PROFESSIONAL PAPERS

ON

INDIAN ENGINEERING.

VOL I—1863-64

EDITED BY

LIEUT COL J G MEDLEY, R E, Assoc Inst C E,

PRINCIPAL, THOMASON C E COLLEGE, ROORKEE

SECOND EDITION

ROORKEE

PRINTED AND PUBLISHED AT THE THOMASON COLLEGE PRESS

CALCUTTA THACKER, SPINK & Co BOMBAY THACKER, VINING & Co

MADRAS GANTZ, BROTHERS LONDON E & F N SPON & Co

1870

ROORKEE
JAMES JOHNSTON, SUPERINTENDENT,
THOMASON COLLEGE PRESS

PREFACE TO VOL I

THE First Volume of these Papers is now completed Their publication has been, I may honestly say, a success, and I beg to record my acknowledgments to Contributors and Subscribers accordingly. I have had the pleasure of receiving many more Original Papers than I could have expected, while from the Public Works Secretariats of the Governments of India, the N W. Provinces, and the Punjab, I have received many Official Reports, &c, of great interest I have also to thank some of the Railway Engineers for some valuable Papers No endeavour will be spared on my part to make the next Volume better than its predecessor, and I trust that many, who as yet have hung back, will come forward as Contributors or Subscribers

While I have impartially selected for publication the most interesting and useful from the mass of papers which have been sent to me, I have also endeavoured to give as great a variety as possible, so as to suit all tastes Thus each Number has contained papers on Civil Engineering, on Architecture, and one paper at least on Surveying and on Military Engineering

I may mention that 850 copies of each Number are now struck off, and that a copy of each has been sent to the Institution of Civil Engineers, to the Editor of the R. E Professional Papers, and to the Asiatic Society of Bengal The new Edition of Number I is now ready, and 150 Copies of

that and the following Numbers have been transmitted to Messrs Smith, Elder and Co, for Subscribers in England

In Number VI, I hope to commence the publication of a continuous account of the operations of the Great Trigonometrical Survey of India from the commencement up to the present time And in the same Number to publish the first of a series of Tabular Statements of Rates of Work prevailing in the several Provinces of the country at the same time, which can hardly fail to be of great use to the practical Engineer The blank Tabular Statements which I have sent out with this view, have been returned duly filled up from *two* Provinces only as yet, and I have to record my acknowledgments to the Controllers of Public Works Accounts of Bengal and Hyderabad accordingly, but I hope that the evident utility of these Statements will induce the other Controllers to comply with my request in like manner, though I am fully aware of the demands on their time made by their official duties

No VI, being the First Quarterly Number of the new Volume for 1865, will be issued on the 1st February The price of the Volume (Four Nos) will be 14 Rupees to Subscribers, *payable in advance** to the Editor at Roorkee by Treasury Draft or Cheque on any Indian Bank, to Messrs Thacker and Co, Calcutta or Bombay, or Messrs Pharoah and Co, Madras The price of each single Number will be Rs 4 To Subscribers in England the price will be 28*s* for the Volume, or 8*s* per Number, payable to Smith, Elder and Co, London

J G M

* The expense attending the publication of these Papers being considerable, and the Editor having no time to dun, Subscribers must be good enough to understand that until their Subscriptions are paid their copies cannot be sent to them

INDEX TO VOL I

LIST OF PLATES

ENGRAVINGS

LITHOGRAPHS

DESCRIPTION OF FRONTISPIECE

The Solani Aqueduct, by which the Ganges Canal is carried across the valley of the Solani river, consists of an earthen embankment or platform, raised to an average height of sixteen and a half feet above the country, having a base of 350 feet in width, and a breadth at top of 290 feet On this platform the banks of the Canal are formed, 80 feet in width at top, and 12 feet in depth These banks are protected from the action of the water by lines of masonry retaining walls formed in steps extending along their entire length, or for nearly two and a quarter miles north of the Solani.

The river itself is crossed by a masonry aqueduct, which is not merely the largest work of the kind in India, but one of the most remarkable for its dimensions in the world Its total length is 920 feet, its clear water-way 750 feet, in fifteen arches of 50 feet span, each The breadth of each arch is 192 feet, its thickness is 5 feet, its form is that of a segment of a circle with a rise of 8 feet. The piers rest upon blocks of masonry sunk 20 feet deep in the bed of the river, being cubes of 20 feet side, pierced with four wells each, and undersunk in the usual manner. These foundations, throughout the whole structure, are secured by every device that knowledge or experience could suggest, and the quantity of masonry sunk beneath the surface is scarcely

less than that visible above it The piers are 10 feet thick at the spring of the arches and 12½ feet in height The total height of the structure above the valley of the river is 38 feet It is not, therefore, an imposing work when viewed from below, in consequence of this deficiency of elevation, but when viewed from above, and when its immense breadth is observed, with its line of masonry channel, nearly three miles in length, the effect is most striking

The water-way of the Canal is formed in two separate channels, each 85 feet in width The side-walls are 8 feet thick and 12 feet deep, the depth of water being 10 feet A continuation of the earthen aqueduct, about three-quarters of a mile in length, connects the masonry work with the high bank at Roorkee, and brings the Canal to the termination of the difficult portion of its course

This great work was designed by Sir Proby T. Cautley, and chiefly executed by Capt (now Lieut -Col) A G Goodwyn, R E It occupied seven years in construction, and cost Rs. 32,87,000

EDITOR'S PREFACE

THE object and scheme of the present Series of Engineering Papers, whereof the first number is now published will be best explained by the following extracts from the Circular issued in April last —

"It has long been a matter of regret that no means exist of recording from time to time the experience of Officers of the Engineering Department in India for the benefit of their contemporaries or successors

"It is, in fact, not merely a subject of regret, but of serious inconvenience that is almost daily felt by those engaged in Indian Public Works, whilst year by year Officers of high attainments leave the country, carrying with them their experience of the past and their projects for the future, which are alike lost to Government and the Public

"The peculiarities of Indian Engineering have greatly increased this inconvenience It is not often easy to procure Professional Books at all, and when procured, they are too often found inapplicable to Indian specialities The difficulties and delays in travelling render it generally impossible for an Engineer to consult *vivâ voce* with others, while he is obliged to undertake a large amount of subordinate miscellaneous work, which elsewhere would be made over to contractors, making it peculiarly desirable, that in spite of all the above difficulties, he should have a certain acquaintance with almost every branch of the profession

"It is moreover, not a little mortifying that of the great Works that have been executed in this country, with scanty means and in the face of extraordinary difficulties, so few records exist, that even to the professional public their very names*

are all but unknown This applies to Military, quite as much as to Civil Engineering, and this is still more to be regretted at the present time when the separate existence of the three Corps of Indian Engineers has just been terminated One praiseworthy exception there has been to this neglect, in the Madras Series of Professional Papers, which appears, however, to have lately ceased

"It is unnecessary to investigate the causes which have led to the above deficiency Some of them at least it is believed no longer exist, and it is thought that an attempt may now be made to start, on a proper footing, a Series of Professional Papers on Indian Engineering, to which Military, Departmental, Railway, and other Engineers, should be invited to contribute This Series would contain, 1st, Original papers descriptive of works actually executed or in progress in any part of India, 2nd, Official documents, reports, projects, and the like, which Government may place at the Editor's disposal for publication, 3rd, Original papers on professional subjects or on scientific subjects bearing on the profession, 4th, Original designs and projects, 5th, Occasional translations and reprints of articles of importance which are not generally accessible to the Indian Engineer The numbers of this Series would be issued from time to time as they were ready, at a certain price to Subscribers only, and afterwards to the general public at an enhanced rate

"The Government of India has promised to authorize the transmission of Professional Papers from among the Records of the Public Works Department, or from those of the Local Governments for publication in the proposed Series, and the object of this Circular is to ascertain what amount of assistance, both literary and pecuniary, can be looked for from individuals, when if a proper degree of support is assured, the first number will be issued from the Roorkee Press as soon as possible

"The undersigned will be happy to register the names of Subscribers, and to receive any MSS that may be entrusted to him for publication He will avail himself of the best Professional assistance within his reach in the task of selection and editing, and suggestions are freely invited from *all*, but Original Papers will not be altered or abbreviated without the consent of the writers It should be borne in mind that elaborate papers on general principles are not so much required, as records, however brief, of actual Indian practice For the former, few Engineers actively employed can find leisure, for the latter a couple of hours spent at the desk may often suffice to record results of the greatest value to the profession at large"

The following was also addressed to the Chief Engineers of the several Indian Railways —

"THOMASON COLLEGE, ROORKEE,

1st May, 1863

"MY DEAR SIR,—I beg the favor of your distributing the accompanying Circulars to such of your Officers as are likely to be interested in the scheme,

and I shall be glad if you will give it an active support It is not meant to be an Official or Departmental or Military scheme, but simply Professional, and it is to the profession at large that I look for assistance in supplying an acknowledged and long felt deficiency

"Contributions will be published with or without the name of the writer as desired; and, *if requested* (not otherwise) I shall be happy to abbreviate or revise any paper that may be sent, otherwise it will be printed entire or returned if unsuitable In all cases every care will be bestowed on the press work

"Yours sincerely,

"J G MEDLEY, MAJOR,

"*Royal Engineers*"

Such being the objects proposed, it may be worth while to consider somewhat more at length the field in which we have to work

Under the *first* heading, named in the Circular, a short list has been given above of the Public Works already executed, regarding which information is desirable As noted, this is exclusive of the very important Railway Works still in hand, or already completed Some accounts of these have occasionally been given to the Profession in England, but I hope that this circumstance will not interfere with our nearer (if not prior) claim in this country. As every year is tending more and more to amalgamate the three branches of the profession in India—the Military, Departmental, and Railway Engineers—so I hope that each will recognize the claims of the other two to a mutual interchange of professional knowledge If Science, like Art, knows no distinction of country, it ought not, *à fortiori*, to recognize petty distinctions amongst the same countrymen

One other remark I would made under this most important of our headings Too much stress can hardly be laid on what is explained in the Circular above, viz, that records of facts are wanted, rather than disquisitions on general principles. So far as the principles of Civil Engineering are based directly upon Mathematics, they may, of course, be said to be known, but every practical Engineer knows how seldom this is the case, and what large allowances have to be made in executing works according to Mathe-

matical formulæ. So far as this is the case, it may be said that the principles of Civil Engineering are still in their infancy—and the only way such principles will ever be clearly eliminated, will be, as in all exact science, by a patient observation of facts. We have to deal with the great forces of Nature, and to make them our servants instead of our masters. Let us rest assured that however irregular those forces may appear, it is simply our ignorance that prevents our comprehending their laws. The more we know of Nature, the more we shall learn that *nothing* is irregular, and that even the earthquake and volcano are governed by fixed laws, as regular and certain in their operation as the law of gravity itself.

There is no Engineer in practice who may not add to our storehouse of facts, and that with comparatively little trouble. The mere statement that the price of *kunkur* is so and so in a certain district, is a useful fact so far as it goes, and, if that is supplemented by a statement of the conditions under which it is found, and of its good or bad qualities, it at once rises into a fact of importance, useful as a guide in other parts of the country. This brings us, indeed, to the consideration of a very important class of facts whereon information at the present moment is much wanted—I mean the rates of Work, and the resources of the different districts of India, as closely connected with this question of rates. The late rise in the prices of labor and materials, and the competition between the Railway and Government Engineers, have largely increased the rates for work all over India, but the ratio of that increase has been so irregular, and often so arbitrary, that it is very desirable to have a comparison of data from different districts. Any Engineers, therefore, who will take the trouble to draw out detailed Statements of Rates of actual Work, as executed in their districts, especially if accompanied by notes of the several circumstances determining these rates, will have contributed valuable data, which can hereafter be tabulated for comparison.

And, in reference to this, it may be useful to offer a few remarks on the Financial result of Engineering works, an aspect of the question but too commonly overlooked by Engineers as something

either out of their province or beneath their consideration Yet surely the adaptation of means to the end—or of the end to the available means—is of the highest importance in this as in other sciences, and no Engineer can be a sound or a safe guide to his employers who neglects it As no man would propose or attempt the execution of any particular work without providing the necessary tools and workmen, so neither would an Engineer be justified in projecting or undertaking any great work without counting the cost beforehand, and estimating whether or not a fair return might be expected for the money laid out Were this constantly kept in view, we should see fewer unfinished works and fewer unremunerative complete ones both in India and England It is true that owing to various causes, the functions of the Engineer and Accountant have been too much blended in this country, especially in the Department Public Works, so that in fact, it has often seemed as if the chief use of Public Works was to produce a complicated system of accounts, but without running into this extreme, a sound knowledge of the two principles of Engineering Finance is essential to the requirements of every Public Works Officer

An acquaintance with rates of work, and their local variations will do much to assist us in defining the first cost of a work pretty exactly—the Financial returns to be expected from it cannot always be so clearly foreseen, and the true theory of such a calculation is a point deserving of much attention While the direct returns, either from the water-rent paid for a Canal of Irrigation, or the tolls derived from a Railway or a Navigable Canal, admit of simple calculation, these are often, especially in India, barely remunerative, forming, as they do, but a small proportion of the beneficial results really derived from the work in question The increase to the productive resources of the Land (caused by a Canal), and the diminution of the cost of Carriage, by a Road, are as absolute increments to the wealth of the country as the more direct returns mentioned above, and a thorough acquaintance with the true principles of Engineering Finance, would enable them to be as accurately estimated.

So too, the whole question of Railway tariffs, the ratio of working expenses to gross returns—the deterioration of capital stock—the relative cost of high and low speeds, are all subjects of great value Here, then is a field to which I would beg to draw attention

Under our *third* heading—Papers on Professional subjects, or on Scientific subjects bearing on the Profession, is included the wide range of Engineering principles, based upon data accurately recorded. While all can register facts, it is not given to all to generalize those facts into guiding principles, but many can do so and will, I hope, help in the good work Here, again, it may be well to particularize as to the points in which our information is still very deficient

Of the laws of Running Water in large Rivers and Canals, we know little The formulæ given by Du Buat, Neville, Eytelwein, and other able writers useful as they are, have been chiefly derived from experiments made in small streams, and require considerable modifications when applied to large ones The laws of Silt-bearing Rivers, and their effects upon Irrigation, Navigation, and Inundation, are still undefined Scarcely ten years ago, the conflict of opinion on the grave question of the retention or removal of the Damoodah Embankments in Bengal, showed how little had been done to make a practical application of what was already known on such a subject

The best forms of Falls and Rapids—the comparative advantages of Open Dams and Weirs—the combination of Irrigable and Navigable facilities in the same Canal—the best method of measuring and selling the water to the cultivator—are all subjects open to discussion in connection with Hydraulic Engineering

In other matters the question of Railway Gauge and Railway Gradients have been compromised rather than settled the respective advantages of Railways, Tramways, Metalled Roads, and Navigable Canals, are still open questions as far as India is concerned.

The relation of Cantonments, Forts, and Hill Stations to each other, with respect to the accommodation of Troops, the best arrangement of Cantonments, and the details of Barracks, Hospitals,

and other Military Buildings, the Sanitary arrangements required for them, as well as for large Native Towns—the provision of an ample Water-supply and their efficient Lighting by Coal or Oil Gas, or otherwise—are all questions which Indian specialities have to a great extent prevented being determined on the same principles as would apply to them in Europe

The subjects of Domestic and Ecclesiastical Architecture, as applied to European requirements in India, is also one that deserves much attention Not to mention the hideous specimens of public buildings which deface our older Cantonments and Civil Stations, it must be acknowledged that few even of those erected in latter times fulfil the necessary requirements

The *fourth* heading—Original Designs and projects—is also a very important one Many have been drawn out, from time to time, by able men, submitted to Government, and laid aside for [illegible] funds Of these it is hoped that some may be presented in [illegible] pages, and that many other new ones will be published, and their merits carefully discussed While wild ideas, roughly sketched, will be all but useless, carefully designed projects, considered in both their Engineering and Financial aspects, may be expected to be amongst our most valuable papers The Government of India has already shown its anxiety to afford all reasonable facilities for Companies or private individuals undertaking such works, and their explanation and discussion in these papers may be the means of affording information to those in England, who are quite ready to invest their capital in such undertakings To those inclined to labor in this direction, and to bring their skill and knowledge to bear in developing the resources of India, it may be useful to suggest a few of the various directions towards which such projects may tend.

The great lines of Railway connecting the chief Military and Commercial stations throughout the Empire, are rapidly approaching completion Of the subordinate lines of communication, whether light Railways or metalled Roads, many are now in hand, but many more remain to be constructed, and projects for any of

the remaining lines, pointing out their advantages, and clearly defining their cost, will be very useful. Of Irrigation Canals, that are required to increase the productive resources of the country, two have already been designed (the Soane and Sutlej), and very complete reports and estimates printed. It is probable that one or both of these may be undertaken by joint-stock Companies, it being now generally understood that Government prefers this arrangement for remunerative works, instead of undertaking them itself. In the Punjab alone, three more great Canals may be said to be only awaiting competent Engineers and sufficient Capital to be opened with every chance of fair profits—one from the Chenab, for the irrigation of the Rechna Doab; one from the Jhelum, for the Jhuch Doab; one from the Indus at Kalabagh, for the Sind Sagur Doab. But there are doubtless many other vast sterile tracts in India which only require water to become fruitful and populous.

The system of Tank Irrigation, so universally prevalent in Southern India, but only partially developed in the Upper Provinces, might, it is believed, be extended with great benefit, especially to the undulating ground at the foot of the hills, and doubtless, too, in Central India. I believe this to be a very promising field for projects.

The subjects of the Improvement of Indian Rivers for Navigation is one of great importance, and deserves more attention than it has hitherto received. By a proper combination of Levees and the Lock and Dam system, I believe much might be done to control their shifting course and deepen their navigable channels. Even if the question is one of expense, it is desirable to know what are the limits of that expense as exemplified on any particular River.

The subjects of Lighting, Drainage, and water supply for Native Towns and Cantonments have already been noticed under the third heading. Projects for these, as applied to any particular City or Cantonment, would be valuable; there are few large towns that could not afford to pay well for such luxuries from their local funds only, if proper designs were submitted.

I have now said enough to show the large field that has to be worked—it might indeed be extended almost indefinitely. I have only, in conclusion, to call upon all good and true men to aid me in my task, some by helping to raise a worthy memorial of what has already been accomplished—others by pointing out what still remains to be done

J G M

No I

REPORT ON THE PASSES OF THE ARACAN MOUNTAINS.

Extract from Reports on the ARACAN FRONTIER, *drawn up in fulfilment of instructions from the Governor General. By* CAPT (NOW COLONEL) H YULE, R E.

Calcutta, July 5, 1853

TOPOGRAPHICAL DESCRIPTION OF THE ARACAN FRONTIER, AND GENERAL ACCOUNT OF THE PASSES

THE country partially traversed in the execution of the duty committed to me, extends from about latitude 20° 9′ to latitude 18° 12′, or from the Talakh Pass, North of Aeng, to the Alegyo Pass, leading from Sandoway Eastward Yama-Doung (*Great Spinal Ridge* as the term may be freely translated, for it is scarcely a proper name) stretches throughout this tract in general nearly North and South, and at a mean distance of thirty-five miles from the sea-coast, and of about the same from the Irawadee

Entering this part of Aracan from the Westward, we encounter a vast archipelago of wooded hilly islands, the larger of them (Ramree, Cheduba, &c) maintaining a considerable population, though in very low proportion to their area, the smaller, with few exceptions, uninhabited, and, by their close approximation, forming a multitude of narrow channels, exceedingly tedious to navigate The rivers again, which flow down to the sea from the Yoma, diverge near their mouths into an infinity of branches or tidal creeks, separated by low alluvial islands forming a continuation

(though from another origin) of the marine archipelago These islands are covered with dense forest and mangrove thickets, recalling to the imagination what it has pictured of the lagoons of the Niger, or of the deltas of the great Guiana rivers and they rarely afford in their present state localities fit for human habitation

Passing up towards the limits of the tide's influence, we reach the most cultivated part of the country, tracts of rice ground and comfortable villages, interspersed, however, with extensive jungles and forest covered hills Beyond this populated, but not populous, region we reach the skirts of the long spurs of the Yoma, not entirely unpeopled, for hereabouts the Khyen* race establish themselves from year to year, to carry on their tillage, clearing the hills from their dense bamboo covering, burning the clearance, and then dibbling in, even on slopes where footing is hard to find, their crops of hill-rice, with a little cotton and oil seed Their little chalets, (here generally isolated,) raised on long bamboo stilts, crown and dot the hills These habitations are generally changed yearly, or at least after two years, for new seats and new cultivation As we advance into the interior of the mountains these dwellings become more and more rare, and in looking from the higher points of Yoma, and its spurs, the eye generally descries no symptom of human habitation, though in truth there are one or two Khyen villages here and there at long intervals

The mass of the mountains is covered with bamboos, giving an air of excessive tameness and monotony to the scenery After reaching a height of 3,000 feet, or thereabouts, the bamboo is usually exchanged for forest trees, many of them of noble girth and stature,† with undergrowth of rattans, &c, and a great variety of creepers

Looking Westward from the higher points of the chain, we should suppose it to consist of a series of eight or nine detached parallel ridges The unbroken jungle obstructs general views and the acquisition of a correct idea of the structure of the range But a further acquaintance with the mountain tract shows it to consist of a spinal range throwing off very long spurs at various angles, and that these spurs expand laterally

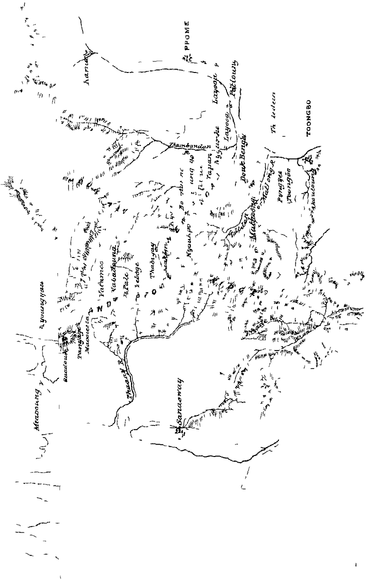
* One of the half wild Indo Chinese races very extensively diffused along this great meridian chain, almost from the frontiers of Assam to its termination at Negrais Throughout the Aracan frontier they are distinguished by the singular fashion their women have of tattooing the face all over in a sort of corduroy pattern

† The Toungoop Pass especially abounds in such one species in particular (I believe a kind of *Hopea*) is there seen stayed on gigantic buttresses, rising to a height of 100 or 120 feet, before it spreads abroad its crown of lateral branches

MAP

TO ACCOMPANY COL. YULE'S

PORT ON THE ARACAN PASSES



LITHO T C FRE

into short ridges parallel to the main range, and connected with it and with each other by comparatively low and narrow necks.* On the Aracan side of the mountains, the spurs extend for an average distance of nearly thirty miles from the central ridge. On the Burmese side the skirts of the mountains are laterally less prolonged, and appear in the Northern portion of the district to run off rather in great branch ranges, parallel to Yoma and of little inferior altitude.

Southward, a singular contrast is presented by the appearance of the two sides of the mountains during the season of my journey (March and April). On the Aracan side, verdure still prevails, the forests are still thickly clothed and hide the soil. Towards Burmah all is desication and death, the hills are like hills of ashes, and the forest a collection of dry dead sticks, scarcely a leaf is visible in this scene of "torrid winter."

The soil, almost throughout the range, is a reddish clay, very favorable to road-making. Rock is rarely visible except in the water-courses. It appears to consist of varieties of highly indurated clay and clay-slate, the strata always elevated to a very high angle. In the Northern portion of the region, towards the Aeng Pass, the Yoma range rises in boldly defined crests and peaks to an average height of 4,400 to 4,600 feet, about Kamyengain it sinks suddenly nearly 1,000 feet in mean height, and assumes a tamer and more undulating character, gradually descending for twenty-four miles, till the grand cone of *Myeng Mateng*, the "Ever-Visible," springs suddenly from the very crest of the range to a height of 4,700 feet above the sea, from its noble form and comparatively isolated position, assuming a grandeur and impressiveness of aspect which at first sight leads one to assign it a vastly greater altitude. Passing this great anomaly, the range sinks again to its former tame and undulating character. Further South, I am less acquainted with the mountains, as I only crossed the range in passing to Prome by the Toungoop Pass, and returning by that of Alegyo, whilst the constant brassy haze which accompanied the rapidly augmenting heat entirely prevented comprehensive views of the scenery. In that Southern portion of the district, however, the Yoma appears to have regained something of its height and irregularity of outline, though still lower and tamer than the mountains above Talakh and Aeng.

* This narrowness of ridge characterises the main range also in many parts. Near the crest of the Alegyo Pass, the ridge of the Yoma is so narrow that its breadth was exactly measured by my walking stick. On either side the hill dropped at an angle of at least 50°, draining on one side to the Irawadee and on the other to the sea.

Not a great deal of animal life is encountered in traversing these wilds The elephant abounds, and his tracks are as frequent on the beaten roads as those of cattle, but he is rarely seen The two-horned rhinoceros also, and the *gour* (or bison of the Madrassees) haunt some of the more secluded vallies The strident flight of the hornbill, and the hoarse voice of the barking deer, occasionally break the silence of the bamboo wildernesses The tiger too exists, and made his existence tragically known during my visit to the Aeng Pass In the Southern Passes, where forest is more abundant, the crow of the jungle cock is heard continually, replaced among the dead and withered scenery of the Burmese slopes by the dreary and unceasing drone of the "dry cicala" The larger streams abound in fine fish which afford occasional sport and profit to the Khyens

Such is the country crossed by the numerous Passes leading from Burmah to Aracan There are two descriptions of road among these, and each Pass is likely, in some part of its course, to partake of either character. *First*, where the road adopts the bed of a stream as its guide and axis, winding along its margin, constantly crossing and re-crossing, or blundering up the boulders of its channel, *Secondly*, where the road attaches itself to the ridge of one of the long spurs, rising and falling as it does, and sometimes with enormous vicissitudes of height, until the main ridge is attained and crossed, generally at one of its highest points These roads scarcely ever quit the ridge, even when a great amount of needless fatigue might be easily avoided by keeping a lower level They are so similar in principle (if one may say so) to the wild elephant paths which I was several times glad to follow during my travels in the hills, that I incline to think all, or nearly all, the Passes have originally been formed by man following in the elephant's track None that I have seen show any trace of artificial formation except the Aeng Pass and part of that leading to Pyng Hence the quality of the road depends mainly on the amount and kind of traffic Where not much traversed by travellers the paths are much obstructed by bamboos and bamboo-roots, and again, where droves of cattle pass frequently, as in the Alegyo Pass, the path is apt to be cut into deep cross furrows The roads through forests are generally best The river roads are always detestable, in fact they are scarcely to be called roads On the whole the character of most of the Passes is much the same

From the valley you ascend an excessively steep and slightly winding

path, generally much ravined by rain, and formed into steps by crossed and twisted bamboo roots. Reaching the crest of the ridge you have occasionally a pleasant level path, spontaneously drained and therefore in good order, running through the thicket like a shrubbery walk, but this rarely lasts long. Following the ups and downs of the crest of the spur, you waste much toil and breath over similar rooty rugged ascents and descents, till, by the time you reach the summit of the main ranges, you have climbed and descended, it may be, ten times the absolute height attained at last. I suppose there is no one of the Passes across which ponies cannot be taken, but at the same time there is no one which you can ride over continuously, and in most a regard either to your own comfort or to that of your steed, renders dismounting so frequent, that it is scarcely worth while to take a pony.

It is only in the larger channels, and in the deeper vallies, that there is any perennial flow of water.* All the minor tributaries, and nearly all the mountain brooks, dry up early in the season. Hence water is ever an anxious consideration in the higher parts of the Passes. The supply in these positions is derived from springs percolating from fissures in the rocky bottoms of ravines, trickling for a few yards and then disappearing again in the crevices of the channel. The frequency and abundance of such supplies is the strongest ground of preference for one Pass over another. The Aeng and Toungoop Passes are favorably circumstanced in this regard, water being procurable on the higher parts of the former at average intervals of two and three-quarter miles, on the latter of three miles. The Alegyo road on the other hand is one of the worst provided. Often for six or seven miles, once for ten miles, not a drop of water was accessible, except what was carried with us, and for four marches the only supply was derived from small holes in the beds of water-courses, half filled with decayed vegetation, and polluted with bovine and bubaline abominations. When dearth of water is anticipated, each man generally carries a small supply in a bamboo, of which the internal partitions have been pierced, and the mouth corked with leaves. The green bamboo often imparts a nauseous flavor to the water. In nearly all cases I conceive that the water supply would be capable of improvement by the excavation of the rock, and the formation of proper reservoirs. The only instances that I can call to

* On the Burmese side some of the principal water-courses, which were copious running streams in the upper part of their course, become dry beds further down.

mind in the upper regions of the Pass where water is derived from a flowing brook, are at Yeyen, ("the living waters,") where the Pyng road reaches the ridge of Yoma, and the lower guard-house at Wadah in the Aeng Pass. The springs are frequently 300 to 500 paces distant from the road, down the slope of the hill. On the road there is generally, where the water path strikes off, a cleared grassy space where travellers rest and cook, almost the only such grassy spaces existing on the mountains. Such a halting place is called Tsă-Kăn—Eat-Rest.

An idea of the general aspect of the mountains, and relative position of the Passes in the neighbourhood of Aeng, may be had by referring to the Map.

The first Pass to the Northward is that from Talakh. This Pass has fallen much into disuse since the construction of the Aeng road. Previous to that time it appears to have been looked on as the chief of the Northern Passes, and at some period labor has been bestowed on its excavation. An attempt was made to ascend the Pass from Talakh by a detachment of General Morrison's army in the first war, but the party appears to have proceeded only a very little way. On the Aracan side the hills are very severe, and water is at several of the halting grounds very distant. On the top of Koloong (a great spur of Yoma), the road is joined by a branch from Wadah in the Aeng Pass. After reaching the main range, it runs along its ridge for about eight miles. A short distance from the commencement of the descent on the Eastern side there is a permanent Burmese post, called Sakhegain. Owing to this circumstance, I suppose, the road has been altogether disused for the last two years, (whilst the more Southerly roads have been streaming with emigrants,) although before that time one-third of the whole traffic ascending the Aeng Pass is said to have diverged this way by the branch from Wadáh. During my partial exploration of the road as far as Tseintsakan the only living thing fallen in with by the party was a bear plundering a bee's nest. From Sakhegain the road descends very steeply and suddenly to the plains of Ava, and three or four miles from the foot of the mountain, reaches the town of Pyng, a place of some 500 houses, and at the head of a rich and populous district. The Pass from Pyng to Wadáh was traversed in 1837, by Captain V. Magrath, who had been sent with the permission of the Ava Government to recover some escaped convicts. This road from Aeng *viâ* Wadáh to Pyng, is the most direct of all the Northern Passes between the populated districts on

the two side of the Yoma mountains, the distance from town to town being about fifty-six miles by route.

Next comes the celebrated Aeng Pass, of which a detailed Report is given in Appendix A. The road was constructed by the Burmese Government in 1816, or thereabouts. Previous accounts of it, so far as I have seen them, appear to me to be much too favorable, and have thus led to a great deal of misapprehension and unreasonable criticism. A late history of British India[*] speaks almost as if the Aeng road were a mail coach-road to Ava, and the *Times* last year took up the same tone. These ideas are probably based on the words of Captains Trant and Pemberton. The former concludes his account of the Pass[†] by stating that, "taking everything into consideration, there is little doubt that a battalion of pioneers sent one week in advance would render the Aeng road quite passable for an army." Pemberton does not hesitate to say that, "our troops might, with perfect certainty and ease, close the campaign in one season at the capital of Ava by an advance from Aeng, if the most ordinary judgment and care were exercised in the necessary preliminary arrangement."[‡] The interest of the question is now retrospective, but one cannot help wondering what sort of carriage these writers had in view for their invading army, or how they designed to feed it on the march, and after its arrival in the valley of the Irawadee. After the experience of the first war they would scarcely be prepared to throw themselves on the resources of that country. Coolies, bullocks, and elephants, are the only kinds of carriage which can be employed in the Aeng Pass. When Ross's Madras regiment came over in 1826, they had all the elephants of Sir Archibald's army with them. But an army, for the conquest of Ava, could scarcely be provided with elephants in that proportion. That neither coolies nor bullocks are easily to be had, has been proved by the extreme difficulty experienced in keeping 200 men at Naragain supplied with food during the last winter.

Captain Trant says, that the plan of the Aeng road was laid out by the King's Engineers. I should rather suppose it to be merely an old track widened, for its line is worse chosen than that of almost any of the Passes. Still it is a wide made road,[§] free from jungle, and wherever it is in decent repair, is on the whole more easily travelled than the other

[*] Macfarlane's.
[†] Two Years in Ava. By a Staff Officer, p. 113.
[‡] Report on the Eastern Frontier of British India, p. 107.
[§] About 12 feet.

Passes, so that, whatever has been adduced against its employment by a baggage-burdened army, applies to the others, *à fortiori*

Next to the Aeng Pass, Southward, is the Padeng road, leading from Aeng in six marches to a town of that name at the Eastern foot of the Yoma It strikes off from the Aeng Pass immediately North of Bokhyong The whole distance to the crest of the mountain the road runs through bamboo jungle, very undulating, but with comparatively few excessive ascents The supply of water is rather scanty and at long intervals in the upper parts of the road It crosses the Yoma range at Kamyengain, a fine green grassy hill, (rare indeed in these regions,) from which one has an extensive view of the mountains Westward and Southward On the breezy summit I found a new Burmese bamboo fort This had been abandoned about the time of the capture of Naragain It consisted of a double bamboo fence, strengthened with timber, and thickly set with spikes in the usual porcupine fashion of these structures

From Aeng also starts the Pass which takes its name from Myo-theit, ("new city,") a small town South of Palengs and reached in six marches from Aeng The road ascends for two marches the valley of the Tayoo river, passing several Khyen and other villages, and *crosses* the Yoma thirteen miles South of Kamyengain I have not traversed this road, but I crossed it on the summit of the range from which a great part of its course was visible, so that I have been able to lay it down on the map probably with general truth From the Myo-theit road, on the top of Yoma, a branch road strikes off to the left leading to Padeng

A path traverses the ridge of the Yoma the whole way from Kamyengain to near the base of Myeng Mateng a distance of twenty-seven miles It is in the main a better road than most others in the hills The ridge is here quite free from prominent peaks and sudden rises like those in the vicinity of Naragain, and the undulations of the road are comparatively trifling Water too is found at pretty frequent intervals, but not in very large quantities This path connects together the various routes just described, and from its Southern extremity a road descends the Eastern side of Yoma to the Matoong river, and so proceeds to the Burmese towns of Tengdá and Mendoon This road has been much frequented by emigrants during the past season I encountered scores of such families on the ridge of Yoma, and in the Matoong river below, driving numbers of handsome cattle, and carrying their children slung in banghy baskets

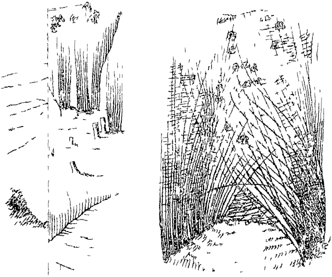


Fig 4

Nature Pass Roads Page 5

Fig 5 Page 8

nboo Stockade at Kamyengain

No road appears to *debouche* in Aracan between Aeng and Maee From Maee two roads enter the mountains, meeting near the top of the range and terminating at Mendoong The Northern road, which I partially travelled, runs from Maee for about ten miles on a tolerable level, but is constantly involved in water-courses It then crosses a ridge of 800 or 900 feet in height, and descends again on the Maee river, on which there is a stockaded Police Post at the mouth of a tributary called the Gamoong The road adopts the course of the Gamoong, and then of a tributary of the Gamoong called the Zeng, sometimes threading from side to side with innumerable windings, sometimes cutting off a bight in the stream by suddenly taking the face of a steep hill, rising from 100 to 1,000 feet, and descending again I first reached this road on the banks of the Zeng, having descended from the mountains along a tributary called the Geng My acquaintance with it extends only from this point to Maee So far it is a bad road, as all those lying much in river beds are Beyond Yoma it descends to the Matoong river and follows its course to Mendoon This town, standing in a bight of the river, does not now contain more than 200 or 250 houses, but it appears to be a place of considerable note, and is the residence of the Provincial Governor The present ruler of Ava, I believe, derived his former title from Mendoon

What further information I have gathered regarding the roads from Maee, and those from Lamoo and Tunlooé has been embodied in the Map and in the Itinerary But I must say that it is very rarely that one gets information of that kind regarding these hill routes from any two individuals to agree What I have to say regarding the Toungoop Pass is embodied in a special note on the line of communication with Prome There also, I have characterized the Alegyo Pass which bounded my investigations on the South

It is to be understood that there are a variety of minor paths ramifying from the different Passes which have been named They are such as are looked on by the people of the country as by-paths or jungle cuts, though probably there is not a great deal of difference between them and any of the recognized *Lan-dau* or royal roads, a few such have been indicated in the Map

REPORT ON THE DEFENCE OF THE FRONTIER AND PASSES

The instructions of the Governor General in Council pointed out, as the

special objects of examination, the line of the Aeng Pass and the Passes near it These embrace (1), The Pass from Jyng, with branches to Talakh and Wadáh, (2), The Aeng Pass itself, from Maphe to Aeng (3), The Jadeng Pass, joining the last at Bokhyong, (4), The Pass from Myo-theit to Aeng, (5), Ramifications of these roads leading from Maphe, Padeng, Myo-theit, Teingda and Mendoon, but all concentrating at or near Aeng

These Passes, indeed, give Aeng its main importance It is a small place, the centre of a district sparsely and scantily peopled, and the invasion of which by a Burmese force would be an insult, rather than lead to any great amount of injury From Aeng, however, a road opens Northward into the most populous and valuable parts of Aracan The difficult discussion of the probability of such an invasion forms no part of my task There is no *impossibility* in it, and my instructions, assuming that there are to be defences, limit my commission to the duty of pointing out where and what they shall be

There are, in fact, a score of paths by which a predatory band might make a raid upon the district One might as well try to hold water in a basket as to stop all these by posts and garrisons The points that seem desirable and practicable are—1st, To have a small force at or near Aeng to give protection against such forays, and that in a position where it could maintain itself till reinforced, if the invading force should be in unexpected strength, and have ulterior designs, 2nd, To occupy one of the principal passes (viz, the Aeng) in force, so that we should have the power of advancing without needless obstruction, if it be desirable, 3rd, To render it practicable for any part of our force in that Pass to move to its flank upon the minor Passes when necessary, 4th, To keep up good information of what is going on beyond the hills, and on the minor lines of road

I would not attempt to guard these minor Passes by establishing posts on the crest or elsewhere in the mountains The multiplication of such posts would lead to expense and would harass and disorganize the troops The Aeng Pass is of consequence, not so much from any superiority in the selection of the line, as from its being a made road, always regarded as the highway into Burmah, and from the superiority of the supply of water. The position of Naragain too on its crest, has acquired so much prestige, and from its dominating aspect overlooking Aracan, *appears* to give its possessors so completely the power of swooping down on the province below, that its occupation by the Burmese last year threw the district into

perturbation and alarm, a large proportion of the inhabitants of Aeng and its neighbourhood deserting their homes in consequence. The possession of Naragain by the Burmese should therefore not be risked again, *i. e.*, it should be held by us in force. To hold Naragain, which is thirty-one miles from Aeng, involves the maintenance of posts of communication, whilst the force designated for the protection of Aeng will also be the support of the chain; such posts have indeed been maintained in varying strength for many years, though Naragain never was, until the Burmese made us aware of the necessity by occupying it themselves.

For the main support of the Aeng Pass and the protection of the country about Aeng, two positions offer themselves, one at Bokhyong, the other at Upper Aeng. Both have advantages. Bokhyong covers Aeng from any advance by the Aeng or Jadeng Passes, or from Talakh. It is also in many respects a good natural position, but does not contain water within what could be conveniently rendered a part of the defences. A well, however, could be dug immediately under the protection of the works. Aeng, again, is nearer communication and reinforcement by water, and in its precincts all the neighbouring Passes concentrate. But the only suitable military position (without extensively disturbing the houses and gardens of the village) is on a low eminence, (at present covered with dense thicket, rising like an island from rice-fields, subject to inundation,) a situation in which one would dread to place troops. The distance too from the first post of communication towards Naragain would be augmented two miles, and the march is even now a severe one, less from the distance (ten miles) than from the number of excessive ascents and descents. I therefore would retain Bokhyong as the post.

It is a flat topped hill rising some 70 or 80 feet above the flat valley of the Aeng river. The latter flows at the distance of 200 yards under a steep bank, varying from 30 to 70 feet in height, and at a similar distance in front, the position is covered by the deep ravine of the Bo Nulla, (or Khyong,) from which the place is named. The site was selected last year by Captain Nuthall, and occupied by part of the Aracan Light Infantry since July. Slight field works were also thrown up at various points by Captain Nuthall. These were, however, far too extensive in outline, embracing a great deal beyond the hill, to the summit of which I mean to confine the new projects. The post at Bokhyong should be capable of accommodating at least 120 men. The proposed work, con-

sists of a rectangular stockaded inclosure, 68 yards by 58, with flanking works at three of the angles, each provided with an earthen barbette for a single six-pounder gun. The barracks and other buildings run along the faces of the work, so that their outer walls (flanked and loopholed) form a part of the enclosure. A small parapet covers a piquet, and in the event of actual expectation of a hostile movement, I would also establish an outpost with one field gun at a spot on the high bank commanding the open bed of the river for a long way up, and at the same time completely under the fire of the main work. A well will have to be dug in the low land, this will probably require to be 40 or 50 feet deep.

In ascending the Pass from Bokhyong, the first post of communication to be occupied is Thurówa, distant ten miles from Bokhyong, and situated just below the junction of the Aeng and Thuro rivers on the right bank of the united stream. The present guard-house stands in a hollow, closely commanded by the adjoining heights, and indeed it is not without incurring other inconveniences that any post can be found in these hills free from this objection. But, as the selection of a site for a military post at all, implies the anticipated possibility at least of an attack, that selection should not be left open to so manifest an objection as command within pistol shot. I therefore propose removing the guard to the top of an adjoining round hill, about 200 feet above the river. This is higher than I could wish, but there is no medium to be found. The hill is covered with dense bamboo jungle. I cannot therefore give a plan of the work, but in fact it need only be a simple guard-house adapted for twenty-five men, of the usual Aracan structure, with a palisaded enclosure. Water is procurable from the brook on the south side of the hill as well as from the more distant river Aeng.

Wadáh or Wadát, twelve and a half miles from Thurówa, is a position of more consequence on account of the junction of the Pyng road there. I quit the present site of the guard for the same reason as at Thurówa, but very reluctantly, as it is immediately at the fork of the two roads, and has a very convenient supply of water. I have, therefore, been compelled to select a position in rear, and I find none suitable without receding nearly a mile. Here the road passes along a narrow ridge which, at the point indicated, swells out into a knoll just large enough for the intended structure, a block-house for thirty-five men with a stockaded enclosure, on the same general pattern as that described hereafter for Naragain,

Water I succeeded in finding in the ravine on the south of the position, though at 500 yards distance, and with a steep descent to it. This must be palliated by making a good road to the spring. A minor convenience of the removal of the guard at Wadáh will be, the more equal division of the two marches between Thurówa and Naragam.

Yogyee lies immediately at the foot of the last ascent to the summit of the Pass, distant five miles from Wadáh, and one and a half from Naragam. A guard has been maintained here occasionally for some years, and it was kept up even whilst the Burmese were in possession of Naragam, though from its position in a hollow at the foot of the steep descent it must have lain much at their mercy. The path by which Captain Nuthall turned the Burmese position strikes off here, and it is a favorite halting place for travellers on account of the good supply of water, so I incline to retain a small post here to be supplied from the Naragam garrison. The present guard-house is a wretched hovel, picturesquely situated just under the road. The new building, a small blockhouse for twelve or fifteen men, will be constructed on a knoll a few yards further up the road.

We now come to Naragam, which is reached from Yogyee by an excessively steep and somewhat winding ascent up the face of the mountain. Reaching the summit of this face, the road passes through a hollow some 50 yards in mean width, between two knolls, which rise about 60 feet above it. From side to side of this hollow, immediately on the verge of the steep, runs the Burmese stockade. For the protection of their flanks, they trusted apparently to the density of the thicket and the great steepness of the declivity. Their huts occupied the hollow itself, and the rear was closed by a mere wattled fence and gate. It is obvious that the position is a one-sided one, and that though it suited the Burmese, it is quite unsuited to us, as a post, being in fact when approached from the Ava side a mere hole between two commanding hillocks. The hill on the north, (or our left,) affords, however, a very good position. It commands the road through the hollow, and for a musket shot towards Burmah, as well as for a shorter distance on the steep descent to Aracan. The work proposed for this knoll consist of a blockhouse, or loopholed timber barrack of two stories the upper story projecting so as to afford a *machicoulis* or vertical substitute for flank fire. The building is adapted for the usual accommodation of fifty men,

in the upper story, but is capable of holding more on emergency It is intended to surround the work by an outer stockade, and to arm this with two mountain howitzers

At the time when I visited Naragain, the troops were hutted in the hollow occupied by the Burmese stockade, a position equally unsatisfactory in a military, and (from the wretchedness of the cover) in a sanitary point of view It was necessary, in the near prospect of the rainy season, to take immediate steps for remedying both evils The construction of such a blockhouse would provide at once good cover and a defensible military position I therefore acted on the authority intrusted to me by the Governor General in Council, by ordering the prompt commencement of that work It was begun vigorously as soon as workpeople could be procured, but on my return to Kyouk Phyoo in April, after the completion of my tour, I learned that the lower story had scarcely been completed when the whole of the laborers ran away I therefore recommended the overseer in charge to have the finished part at once roofed in, so as to afford the best cover available, and this I trust has been done

Water is a difficulty at Naragain It is found at two places respectively 600 and 700 yards from the post, both down the eastern slope of the hill and not abundant in quantity Still it supplied 200 men during the last cold season, (not without grumbling it is true, especially among the Hindoos of the 65th Native Infantry,) and with some labor expended in forming reservoirs, it will be ample for the smaller permanent garrison Iron water-tanks should be provided for this post and for Wadáh, in case of any temporary investment, and these should be kept filled and habitually used I have no further works to propose for the defence of the Aeng Pass

The Pyng Passes leading to Wadáh and Talakh also deserve consideration The former is the most direct passage from Burmah to Aracan It is also a pretty good road, as these roads go, has a moderately good supply of water, and was a good deal used by travellers before the present war The branch to Talakh abounds in very steep ascents and descents, the water supply is on part of the road at great intervals and at some of the halting places very distant It has of late years been little used, and I do not think a hostile attempt by this road probable Still, as such an attempt is possible, and as the road is the most Northerly of the Passes, and that debouching in greatest proximity to the valuable part

of the province, I do not feel at liberty to disregard it I cannot think, however, of extending the inconvenience and expense of detached hill posts, by recommending the establishment of an out-post on the upper part of this Pass, East of the junction of the two branches * The branch to Wadáh will be sufficiently watched by the comparative increase of strength given to the post there in the chain of communication with Naragain, and the termination of the Talakh branch, at the town of that name, should be covered by the re-establishment of an outpost which was formerly maintained at that place

No Passes appear to issue on the Aracan side between Aeng and Maee The Passes at Maee are tolerably direct though far too much involved in river channel to be good roads They were, however, I believe, used in former times by the Burmese troops, and I visited the locality, partially traversing one of the Passes to select a site for a post covering their debouchment among the Maee villages, I consider now, however, that by the extension of our Pegu frontier to Meaday, these Maee Passes will be rendered harmless, and no steps need be taken on the side of Aracan for their defence

I have completed the enumeration of works recommended for construction, but there are other measures which I think might be advantageously adopted for perfecting the security of the frontier

Nearly all these hill roads are much frequented by travellers, petty merchants, drovers, with bullocks and buffaloes, emigrants from Burmah, &c, and from all we hear of such grievous stories of the prevalence of robbery on the hill frontier, attributed both to Burmese bands and to the *Arangs*, or wilder Kyengs of the Northern districts, one can scarcely doubt their having some foundation The suppression of such crime and the watching of any movements towards the minor Passes might I think be well effected through the agency of that shrewd and energetic man, Nakecke, the Kyeng chief, to whom the Governor General presented a sabre and rifle for his aid rendered in the surprise of Naragain For this purpose, I would empower him to take into permanent pay twenty to twenty-five men of his own race,† who should be provided with good muskets

* There is a part of the road on the ridge of Koloong somewhat east of Tantaben Tsakan where the ridge is scarcely wider than the road, with a steep descent of 1,000 feet on either side One may conceive circumstances where it would be worth while to obstruct the road by cutting it across at this point

† Say the chief at 25 rupees 1 Jemadar at 15 rupees 24 men at 7 rupees

by Government, and should be employed under him constantly in patrolling the Passes and hill roads from the Talakh river to the Mace roads, and in collecting information regarding, and watching any movements on, the Burmese side of frontier * There are many sites in the vicinity of the Yoma, south of the Aeng Pass where Kyeng villages might be established and supported by what is called *Jhoom* cultivation, (*See* Topographical Description,) but dread of the neighbouring plunderers is constantly assigned as a reason for the unpeopled condition of the mountains in that tract A man like Nakeeke, when seen to be endowed with authority and power to protect the people under him, could, and I believe would, do much to promote the settlement of increased population, which would, after all, be one of the best safeguards of the frontier As nearly all Kyengs possess fire-arms, (such as they are,) I would make it binding on them to turn out *en masse* on extraordinary occasions, when summoned by Nakeeke It would of course be necessary for the civil officer of the district to keep a strict eye on the chief, lest his authority and armed followers should be turned to wrong uses Indeed, it is desirable on all accounts that this district of the main land should be more familiarly known to the authorities than it has been hitherto

The Commissioner of Aracan will give a more valuable opinion than mine on the preceding suggestions It is to be remembered that Burmah is now † swarming with banditti, and that efficient measures are likely to be wanted to prevent their encroaching on our Aracan territory One of the first tasks of Nakeeke and his people would be to improve the road now existing along the crest of the Yoma from Kamyengain to near Myeng Mateng, and to extend it northward to Naragain, and the crest of the Jyng road, so that a detachment from Naragain might move rapidly on the minor Passes on emergency, as well as to facilitate the Kyeng levies' own movements I do not anticipate that this would require more than the clearance of bamboos and under-growth, a task which would be performed by Nakeeke and his paid retainers without additional expense It might be as well too that detachments from the posts on the Aeng Pass should occasionally patrol the minor Passes, for example, from Waddah along the Jyng road This, rightly superintended, would tend to the

* With a view to the protection of travellers it would be a great advantage if we had the control of the roads to the eastern base of the hill I brought this to Captain Phayre s notice when there was yet a prospect of treaty with the Ava Government

† In the beginning of 1853

safety of the roads and give confidence to travellers and emigrants. Neither would it be a despicable consideration that the men (and officers) would become acquainted with the country round them, and that the former should have something to divert them from mere idling and gambling.

The four objects enunciated are thus provided for, the first and second by the occupation of defensible posts at Bokhyong, in the Pass, and at Talakh, the third and fourth, by the establishment of the Kyeng levy.

In recommending the foregoing measures, the unhealthiness ascribed to the positions in the Pass is a very perplexing consideration. The medical returns of former years do not help one, owing to the fact that the detachments of the Aracan corps in the Pass had no native doctor and furnished no sick returns. Even last year, the casualties at the various stations in the Pass are not discriminated, and the fluctuation in the strength of the different posts renders the statistics still less valuable. The combined returns for certain months of last year, furnished by the surgeon of the battalion, and reduced by me to per centage rates, are as follows —

Month		Strength of Force	Per centage of admissions to Hospital per month	Per centage on the strength remaining in Hospital at the end of the month	No. of Deaths
July,	1852,	about 180	9	3·3	
August,	„		4	2·2	
September,	„		5·5	1·7	
October,	„		4	2·2	
November,*	„				
(Latter half)		521	11·4	3	
December,	„	512	28	7·9	2

These returns tend to show that what the natives told me was true, viz., that sickness is most prevalent in the depth of the cold season, and in the rapid transition to hot weather rather than during the rains. The returns for this year were applied for, but have not been received. They would show, I understand, a considerable amount of sickness at Bokhyong. With regard to Naragain and the higher posts, I conceive that whatever sickness existed in the past season was mainly due to the coldness of the nights and the badness of the lodging, and this observation may apply in a great degree also to the posts in the lower ground where the night dews are,

* 15th November, the head quarters of the corps arrived at Bokhyong.

during January, February, and March, exceedingly copious * The erection of the new buildings will, it is hoped, greatly obviate this source of disease A good deal of privation was also endured at the higher posts by the Mugh sepoys, from the want of their usual dried fish, fresh vegetables, &c Should there not be sufficient inducement for the spontaneous supply of these little necessaries, I think it would be well either to take measures for their being furnished through Commissariat Agency, or to make the men an extra allowance, such as would enable them to make their own arrangements, the officers at the same time seeing that they did so

I would not think of again employing detachments of Hindustani regiments at any of these posts, which should be left as formerly to the Aracan battalion The number of men called for by the different posts proposed would be as follows —

Bokhyong,	120
Tharowa,	20
Wadah,	35
Yogyee,	12
Naragain,	50
Total in Aeng Pass,	237
Talakh,	35
Grand Total,	272

These numbers, especially the garrison of Bokhyong, might be reduced in the rains And could that most valuable of all auxiliaries to the defence of such a province as Aracan, a steamer, be granted, I think the garrison of Bokhyong as the support of the advanced posts might be permanently fixed at a lower number

The state of the Aracan battalion, as furnished to me by Captain Barry, (22nd February, 1853,) showed as (put by me in an abstract form),

1	Present at head-quarters (Bokhyong),	196
2	On escort with Captain Baugh's elephants, and temporarily posted in the Toungoop Pass,	86
3	In the upperpost of the Aeng Pass,	192
4	At Sandoway,	105
5	At Akyab,	71
6	At the Kaladine,	20
7	On escort duty,	7
	Total,	677

Omitting the second item as extraordinary, substituting for the third

* During these months in looking down on the vallies, the fog, which fills them in the early part of the day, has quite the aspect of a lake, from which the mountains rise like islands

my preceding demand for the whole of the Aeng posts, and supposing the strength of the other detachments to be tolerably permanent, the state of the corps may be anticipated to run as follows —

2	In the Aeng Pass and Talakh, - - -	272
3	At Sandoway, - - - -	105
4	At Akyab, - - - - -	71
5	At the Kaladine, - - - -	20
6	Escort duty, - - - - -	7
		475
1	Leaving present at head-quarters, -	202
		677

or supposing head-quarters to be at Akyab, as they used to be —

Detachments, - - - - - -	404
At head-quarters, - - - -	273
	677

This is an undersirably small proportion of the corps to have at head-quarters, but I am not prepared to say that an increase to the corps is necessary, *whilst a regular regiment is quartered in Aracan*

As the foregoing plans embrace a small armament of field artillery at two of the posts, it will, however, be necessary that the corps be trained to the use of guns, or that a small artillery company be added to it

To whatever extent the Aeng Pass shall be occupied, I do not think it is well that considerable detachments should be left there at any time without a European officer. I should otherwise fear, not only the deterioration of the Mugh officers and men, but that the guards would become a nuisance and an oppression on the roads, which they are meant to protect Naragain may be dull and unpopular as a quarter, but I doubt its unhealthiness

Before concluding, I would advert to a point on which the present Commissioner has a strong feeling, and on which I agree with him, viz, that Kyouk Phyoo is quite unsuited to be the location of military head-quarters in the province It was probably selected originally as central In a military view it is so no longer As regards any liability to Burmese aggression, the Sandoway district may now be disregarded Of the remainder of the province, the Akyab district contains seven-eighths of the population, and pays nearly two-thirds of the revenue It is the valuable part of Aracan, and where attack would be most serious and least improbable It is the access to this tract

from the Passes which it would be of most importance to cover in case of any attempt upon the province, and in that direction troops could be thrown with much greater facility from the town of Akyab than from Kyouk Phyoo, whilst the communication with Aeng and Talakh would be as direct In the thriving part of Akyab, moreover, tonnage for 2,000 men could be procured and ready in thirty-six hours, at Kyouk Phyoo no boats are to be had *

Briefly to recapitulate, the steps recommended in fulfilment of my commission are —

I The establishment of defensible posts (according to the details furnished with this report) at Bokbyong, Thuröwa, Wadáh, Yogyee, and Naragain, and at Talakh

II The establishment of a small Kyeng levy, under Nakeeke, the *Toungmeng*, or hill chief

III The consideration whether the military head-quarters of Aracan should not be transferred from Kyouk Phyoo to Akyab

The consideration whether a steamer cannot be permanently attached to the province

Minor recommendations are —

1 The completion of the path along the hills connecting the different Passes by Nakeeke and his Kyengs

2 The occasional patrol of the minor Passes under right superintendence, by detachments from the posts in the Aeng Pass

3 Measures for supplying the Mughs in the higher posts with the articles of food to which they are used The attachment of two or three elephants to the force in the Pass would probably be found advantageous, as coolies are so highly paid and so little to be depended on

4 The provision of gunners for the posts by training the Aracan corps to gun drill, or adding a small artillery company

5 That the Pass be not left without a European officer, as long as it is necessary to keep up considerable detachments there.

Note on the line of Communication with Upper Pegu across the Yoma Mountains

As a detailed Report of the Toungoop Pass has been or will be sub-

* Captain Hopkinson

mitted by Lieutenant Forlong, attached to the Madras Sappers, who accompanied the elephant escort from Prome and back, it is not necessary that I should swell my papers with similar particulars, which his ability as a Surveyor, his more leisurely journey twice over the ground, and, his better equipment of instruments,* will have enabled him to record with every fullness I will, therefore, only note what occurs to me regarding this road as a direct communication with Prome

The very favourable accounts which I had received of the Toungoop Pass, and the undoubted fact that it was selected by the Burmese seventy years ago, for the transit of a ponderous idol carried off from a pagoda far to the Northward, led to considerable disappointment when I came to traverse it And learning from Lieutenant Ripley that the Alegyo Pass, leading immediately from Sandoway to the Irawadee had a favourable reputation for directness, I thought it well to continue my journey across the Toungoop Pass to Prome, and to return by Alegyo, in order to see if the latter would not afford a better line for communication with the new provinces The result was entirely in favor of the general line from Toungoop The Alegyo road I found to be not only several miles longer than the other, from Sandoway to its terminus on the Irawadee, (the latter being also lower down the river than the terminus of the Toungoop Pass,) but that it had likewise a very defective supply of water, that the crest of the mountains was higher, that there were more frequent great acclivities on the existing line, and that the tortuous bearings of the secondary ridges were more unfavorable to the construction of a new road And altogether, I consider, on retrospection of all the Passes, that the Toungoop Pass affords the best general line that I have seen for the construction of a main road between the two provinces

One condition to be regarded in the selection of such a road would be, I think, to carry it as far North as possible, other things being equal, so that there should be the greatest amount of time saved in communicating with our Northern Pegu Frontier, and had our new territory extended so far as to embrace Patnagoh and Maphé, I should have recommended the entire re-formation of the Aeng Pass as our high road into Burmah Should our boundary in the parallel of Meaday include the small provincial capital of Mendoon, the line best answering this condition

* The writer getting his orders for Aracan late on a Saturday night, embarked from Calcutta at daybreak on Monday morning, so he was not very well provided in any way

would be one of the Maee Passes I have not seen the Southern Maee Pass, which would be the most direct route in this quarter, and in the case indicated it might be well to have it looked at before the final selection of a line

We confine ourselves to a selection among the general lines of existing Passes, not because the latter afford any special facilities for the construction of a road according to *our* ideas, but because the tediousness of traversing those mountains where paths do not already exist, and where the sites of water supply are not known, would render the problem of selection too unlimited Connecting paths, however, are sometimes found running on, or near, the very crest of the mountains from Pass to Pass (like that which I traversed for many miles from Kamyengain to the Southward) and by following these (armed with a couple of good Aneroids, reaching at least as low as twenty-six inches) and occasionally ascending prominent points of the range, possibly a better line might be found than by merely traversing the existing Passes December, January, and the first half of February, are the times most favorable for such investigation Earlier, I do not know that the jungles could be safely entered, later, I know from unsatisfactory experience, the atmosphere becomes so hazy that general views of the country are rarely to be had

With regard to the line from Maee to which I have alluded, it is to be noted that its selection would add twenty-five miles of apparently rather intricate navigation to the steam voyage The anchorage of the steamers would probably be at the foot of the Maee Creek, abreast of Lamoo, where the charts give four fathoms of water, and from which the communication with Maee would have to be completed by boat to that place, or by boat to Lamoo, and thence by road Steamers lying on the other hand, under the east side of Amherst Island (in three and a quarter to six fathoms) would be spared the navigation of the Ramree Channel, and would have a short and direct communication by boat with Toungoop

Supposing the general line of the Toungoop road to be chosen, I would not waste money in patching or re-forming the existing path A part of the first march on the Aracan side, and nearly two whole marches on the Pegu side, lie in and out of river channels, rendering them impassable for even native foot-runners in the rains The remainder from Bunderó to the crest of the Pass, though it has at intervals tracts of very respectable paths, abounds in excessive and useless ups and downs, adhering as it

does in the usual fashion to the crest of the ridge, whatever be the undulations of the latter But the fact of its being thus carried for thirty miles along one continuous spur of the mountain, suggests, that a good road with a very gentle and uniform rate of ascent, might be laid out along the *side* of this long spur The soil throughout appears favorable to road-making and rocky surfaces are never seen, except sometimes in the actual water-courses The most probable obstacles to such a line would occur in encountering long ramifications of the spur, which it would involve too great an extension of the line to pass round, and too great a violation of the prescribed rate of ascent to pass over The remedy for this would perhaps be found in avoiding such a branch ridge, by transferring the road from one side of the main spur to the other, at those points where its crest sinks lowest The eastern half of the road lying along the Matoong river, at the bottom of a deep valley, I did not see the topography well enough to speak as to its continued suitability for the construction of a road, but there was no obvious difficulty

In any case I would recommend that if a road be made, it should be of width and slope adapted to wheeled carriages As the length of the spur above mentioned along the present path is thirty-five miles, and the height of the crest is only 3,200 feet, an easy carriage road need not be *longer* than a fatiguing foot-path, provided there be no insurmountable obstacle to the preservation of the uniform rate of ascent Such points only deliberate survey can determine It is to be noted that a carriage road lying in the greater part of its course much nearer the valley bottoms than the present Pass, would probably encounter much more frequent and copious supplies of water *

APPENDIX A

Special Report on the Aeng Pass

On the Aeng river no vessels but canoes, and somewhat larger native boats of canoe structure, pass above Krengyuen Ghât, three miles under lower Aeng, there being several rapids in the intervals The road commences at Krengyuen on the right bank of the river, and has been made of good width (about twelve feet), but from the native traffic being entirely carried on in small boats ascending to Aeng, it has been little used and

* A military road on this general line is now well advanced towards completion (1856)

is in parts much grown with jungle It runs among a series of round wooded hills, and passes over one or two of the lower ones For a carriage road one or two of these hills are much too steep (about one in six, and might easily be avoided) There are few water-courses Three or four would require bridging for wheeled carriages, but as stores go up in canoes this seems not worth while

This river is forded or ferried at Lower Aeng, formerly *Aeng* simply, as it appears in Trant's Survey and most Maps, now sunk into comparative insignificance The village contains perhaps sixty houses with two or three decayed pagodas and monastic buildings, (indeed nearly all the monastic buildings in Aracan are in a similar state,) and a large rest-house for travellers, of fine iron-wood timber The latter is little used, the alleged reason, the fear of robbers, the rest-house being at a little distance from the village

From Lower to Upper Aeng the road is wide, and crosses an almost level plain in a loop of the river, much of which is covered with rice cultivation A good deal of labor has been expended on the road here in former times, but the bridges are now gone to decay, and the surface is cut up in many places by the passage of water At two miles from Lower Aeng we again cross to the right bank at the upper town Not many years ago this was a village of some twenty-five houses It is now a thriving place of more than 300, the centre of trade with Burmah by the various Passes, and the first resort of the numerous Burmese emigrants who daily flock across the Yomadoung * The greater part of the town, consisting of two populous streets, is on the right and high bank of the river, where the skirts of the mountains come down to the water side, besides many groups of cottages buried in nooks of the hills among jack trees and plantain gardens

At Upper Aeng the Pass may properly be said to commence, though it does not enter the hills finally for some miles further. Traversing a rough defile, called by the natives *Gates of Aeng*, we again emerge into the strath or alluvial valley of the Aeng river, and at one and three-quarter miles from the town, cross it for the third time at Jadeemow, a small village on both banks Half way in this distance the bridge over a mountain stream is now being renewed As the road goes right across the ravine without any regard to the sinuosities of the ground, although

* This was in 1853

the piles have been elevated quite as high as is safe, there is still a sudden and excessively steep descent to the road-way on both sides, a criticism which applies to most of the bridges further on, now also undergoing renewal

Soon after passing the Aeng river at Jadeemow on an eminence to the right of the road is the position of Bokhyong, selected by Captain Nuthall as the main support of the advanced posts in the Pass, and now the head-quarters of the Aracan battalion Crossing the Bokhyong, or stream which gives a name to the station, the road continues for one and one-third of a mile nearly level, till for the fourth time crossing the Aeng river at the small village of Kwaing-wa, it commits itself finally to the hills The Padeng road strikes off on the right a few yards after passing the Bokhyong, and the road to Talakh goes to the left from Kwaing-wa, following the course of the little river Kwaing which enters the Aeng opposite that village

The ensuing section from Kwaing-wa to Thurówa, (8 3 miles,) with the exception of the final ascent to Naragain, and one or two other steeps in the upper part of the Pass, is the worst on the road The road passes over a succession of bamboo-covered hills from 200 to 400 feet in height, mounting and descending; and at the end of eight and a half miles, finds itself again on the banks of the Aeng river with nothing more gained in elevation than the mere slope of the river bed Altogether ten distinct hills are crossed, each with its steep ascent and descent, the slopes of the lower parts of which amounted (measured, I confess with a very rough instrument) to 10°, 12½°, 16°, 17°, and even in one case to 20°, or to translate into more intelligible figures to 1 in 6, 1 in 4 5, 1 in 3 5, 1 in 3 3, 1 in 2 8 Had the road been carried in a straight line, one might have been more tolerant of such perversity But after all it winds more than it would probably have done if carried along the side of the river at a *gentle uniform slope* In returning to Bokhyong, I descended the river in a canoe, purposely to ascertain if there was any obstacle to such a course, and on the contrary the ground appeared very favorable for road construction

The worst of these excessive declivities is, perhaps, not merely the obstruction they present to traffic of any kind, (artillery, perhaps, might be dragged up, considering the special efforts made in its behalf, but any other wheeled carriage is out of the question,) and the unnecessary fatigue

to the traveller, but the destruction which they bring upon the road such as it is. When the actual inclination of the road is so much greater than any side slope that could be given, the water, of necessity, flows along it instead of across it, these descents in a few seasons become mere rugged ravines, and the process of repair which has been followed, consisting in cutting down the ravine to the bottom in order to get a smooth surface, only increases the future mischief. These remarks apply more or less to many parts of the Pass, besides the section just described.

There is a rest-house for travellers at Tsé-dein, three and one-third of a mile from Bokhyong, and another at Thurówa, besides a guard-house and a very small bazar. There is no lack of water on this part of the line, as several running streams are crossed, besides the Aeng river to which the road recurs at two points, viz., at Tsé-dein, and at Pem-beng-taskán, one and a half miles from Thurówa. These minor streams appear to have been all originally bridged by the Burmese, but the bridges were in decay in 1826.

One of the worst ascents on the road is that from Thurówa after crossing the Aeng river. There are also two intolerably bad steeps near Wadáh. The road repairs had been carried to Yezaindong only, so that I could see what had been the previous state of things. Graphic illustration only can convey an idea of what some parts of the unrepaired road are, unfortunately they show also what the smoothed portions must return to in a couple of years, on such steep declivities. It is not to be supposed that all the road is like this, far otherwise. The soil (a stiff red clayey loam) affords so admirable a field for road-cutting that wherever necessity, or a better genius, has led to a better laying out, *i. e.*, wherever the road passes along a level topped ridge, or on a hill side at a moderate slope with free lateral drainage, it stands in need of no repair and will not want it once in twenty years.

Not long after leaving Wadáh (from which the Pyng road strikes down hill on the left to cross the Aeng river) the road crosses the shoulder of the remarkable conical mountain, Nodong, from which one last and very narrow neck or isthmus brings us to the foot of Naragain-hill. The wearisome monotony of bamboos, among which we have travelled since leaving the river at Kwaing-wa, ceases below Nodong, and is exchanged for fine forest scenery. There is one watering place at Kunaza under Nodong, and just as we are about to ascend the Yoma ridge to Naragain

REPORT
ON THE
ARACAN PASSES

Fig 6 Page 26
On the Aeng Pass

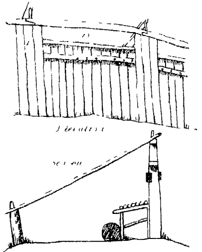


Fig 9 Page 28
Tsetmeng Stockade

Fig 7

Fig 8

Aeng Pass Unrepaired piece of road Page 21

we come on the Pass of Yogyee On the left, below the road is a hovel, occupied as a guard-house, hospital, and residence for the surgeon of the Aracan battalion, with a fine spring of water 250 paces below On the right strikes off into the forest along the steep front of Naragain hill, the jungle track by which Nakeeko* guided Captain Nuthall to surprise the stockade, and a much more rational line of road it appears to be than that which breasts the hill

An excessively steep and fatiguing ascent of one and a half hour succeeds The road here alone breaks into something like zig-zag A height of 1,425 feet vertically, is attained in walking 2,566 yards, but many portions of the ascent greatly exceed in steepness the average of slope which this statement furnishes, (i e, one in five and a half) Hot and breathless the traveller at last passes through the gateway of the Burmese stockade, and finds himself on the crest of the Yoma There are two springs at Naragain, both on the eastern slope, and the nearest 590 yards distant

Quitting Naragain, the road runs for a mile along or parallel to the ridge, and then strikes down the crest of a spur to the Burmese post of Tsetmeng The descent is steep, but by no means so much so as that to Yogyee, and the road is of exactly the same character as on our side, i e, much cut up in the steep declivities, in good order where it has side drainage possible Tsetmeng stands on a knoll crowning the shoulder of the spur along which the road descends to the meeting of the Mankhyong and Khyen Khyong The ridge in front is narrow and the hill excessively steep and jungly all round, except where the road proceeds towards Burmah On this side there is a large grassy encamping ground, from the extremity of which I could see two miles below the post Kyouk Peloo, apparently also abandoned The road does not pass through the Tsetmeng stockade as at Naragain, but under it on the right bank The work is otherwise similar in construction The space on the top of the knoll is very small and the garrison appeared to have been hutted on the grassy space near The road has been blocked up by an abattis 250 paces from the stockade, but not under its fire There was no gate hung, and the work altogether was scarcely completed It had been abandoned finally on the news of the disturbances at the capital

I cannot speak further of the present state of the road, as Tsetmeng

* A Khyen chief of great character and energy

was the limit of my tour on the Aeng Pass The road continues to descend rapidly, and at last almost precipitiously to the Khyen Khyong (eight miles from Naragain) The remainder of the distance to Maee (about twenty miles) lies almost entirely in the bed or the defile of the Man river, abounding in large boulders

There is not likely to be under present circumstances any question regarding the improvement of the line of the Aeng Pass But if there were, two very obvious ameliorations would be—*first*, to carry the road for the whole distance from Bokhyong to Thuiówa up the valley of the Aeng river, and, *secondly*, to wind round the southern shoulder of the Naragain mountain from Yogyee instead of breasting the hill For a carriage road, however, an entire revision of the line from Thuiówa upwards would be necessary

No II

SOANE CAUSEWAY.

Report by CAPTAIN C J MEAD, *Executive Engineer, 2nd Division, Grand Trunk Road, dated the 30th June, 1863, addressed to the Superintending Engineer*

A SMALL portion of the Soane Causeway was commenced as an experiment on the recommendation and design of the late Lieutenant-Colonel Knyvett, then Executive Engineer of this Division, in 1853, and being found to answer, the construction of one and a half miles was sanctioned by Government, and before this was completed, (only about a mile being executed,) orders were issued to submit estimates for completion across the whole of the sandy bed of the river, and also for connecting its western end across the channel along that bank (which even during the dry season is a flowing stream of some depth) with the river bank by a bridge, which could be dismantled during the rainy season

The final estimate on which the work has been completed was submitted by me in 1861, and passed, as far as relates to the Causeway itself, by Government, on the 27th September, 1861, but that portion which provides for the connection of the end of the Causeway with the west bank of the river, across the dry weather stream by an iron pile and timber platform bridge with a small opening supported on boats, was rejected.

The work has been carried on steadily every season since 1860, and was completed in March last

I annex copies of two letters, dated in 1853, from Major Knyvett, then Executive Engineer of this Division, submitting report on the experimental

length then constructed, which may be interesting, and not easily found in the Chief Engineer's or your Office, and of the specification and drawing which accompanied my estimate of May 1861, for this work, which will, I believe, afford all the information that can be required. The only deviations from specification which have been made are in lieu of putting the materials for concrete dry in the bags,* as originally proposed by Lieutenant-Colonel Knyvett (and which, as his work had been very successful, I thought myself all but bound to follow) in all work done since 1860, the concrete has been mixed with water in the usual manner before bagging by your order, that in the latter part of the Causeway we have economized† (also by your order) by using bags made of palm leaf mats instead of old gunny bags, while I this year, on the completion of the work, thought it advisable to order a quantity of loose rubble stone, to be thrown into some slight holes which had been formed by water flowing over the Causeway in some places after the subsidence of the floods, carrying away sand from the down-stream side and forming holes dangerous to traffic.

The difficulties met with in the execution of the work on which report is asked have been, I may say, none except those connected with the preparation, collection, and conveyance of the large quantity of materials required, one of the chief, the conveyance of materials over the sandy bed of the river, was met by the construction of a very rough but effectual tramway out of barrack angle iron. The execution of the work is of the simplest nature and presents no difficulty whatever.

The Causeway, as it now exists, forms from December to June a convenient roadway across the bed of the river Soane, which is about two and three-quarters miles wide, and as the portion executed by Colonel Knyvett in 1853 is still in as good order as when first laid down, I think it may be considered to be a permanent work, but it is, as I have more than once reported, sadly incomplete until some sort of superior dry weather bridge (either such as was provided in my estimate above referred to, or any other construction thought superior by higher authority,) be constructed to connect its extremity with the west bank of the river, where a gap still exists

* I examined some of these concrete bags in 1860, and found that in their carriage from the trough to the site where they were to be placed, the materials composing the concrete were detached, for instance, the lime was at one end of the bag, &c, &c, I ordered the materials to be thoroughly mixed with water and then filled, and, without a doubt, this is the proper way of doing the work.

† The gunny bags became difficult to procure, and cost as much as Rupees 9 or 10 per 100 cubic feet of concrete. This was ruinous, and palm leaf mats, sewn together answered just as well, though not so handy.

of about 950 feet, through which the Causeway cannot be extended, as in January there is generally from six to eight feet of water, and seldom, even in May, less than two or three feet. This is now annually bridged with a miserable temporary Pile and Boat Bridge, not unfrequently liable to breakage under heavy traffic, although constructed of the best materials available on the spot, and which costs annually a large sum for the erection and maintenance.

As this Report is stated to be called for in part as a guide for works of a similar kind elsewhere, I may perhaps, with advantage add that the Causeway is laid with its surface *below* the general level of the sands forming the bed of the river, to avoid its ever acting as a slight sunken weir during floods, which would infallibly lead to its destruction, and that consequently the first flood which fills the bed of the river covers it up with sand, which even, should the water again subside, renders it useless for the remainder of the season, and that at the close of each rainy season it has to be cleared of the sand overlying it (in places where the river has thrown up banks, to a depth of six or seven feet), and that during the dry season it is necessary to maintain an establishment for the purpose of keeping it clear, without which it would be soon covered with drift sand during strong winds.

I should also add that were I called on to design a similar work for another stream, I should recommend its width being at least twenty feet in lieu of sixteen feet. It is true that our width of metal on the Grand Trunk Road is only sixteen feet, and is sufficient, but on the Grand Trunk Road there is no difficulty or danger in case of two carriages passing if the wheels on one side of one or both carriages get off the metalled surface on to the hard earthened side, but on the Causeway on either side of the sixteen feet, is either a high bank of loose sand or a perpendicular drop of from one to three feet, either of which is necessarily a danger to be avoided, and consequently there is frequently some little difficulty in carriages passing unless the cattle are very manageable.

The great advantage of this work consists in its affording a hard good road across the all but impassable sands of this river, it is by no means superior to the metalled temporary roads we annually construct across the similar beds of the minor unbridged rivers in this Division, but in the case of the Soane, from its immense width, the cost of such a road, the earth for which would have to be brought from the banks, would not only be

excessive but we could not, with any available amount of labor, complete and open for traffic for a very long time after the fall of the river rendered its construction or the clearance of the Causeway from sand possible

---

(Letter referred to in previous Report)

From MAJOR F KNYVETT, *Executive Officer, Second Division, Grand Trunk Road, to* CAPTAIN J LAUGHTON, *Superintendent, dated 21st July,* 1853

I HAVE the honor to submit a Report upon the work completed this season in the bed of the Soane River, and also a statement and bill for the expenses incurred in labor and material, amounting to Rs 1,804-11-5

The materials having been all carted to the site I had fixed upon for the experiment, the work commenced by sinking a portable coffer-dam fourteen feet square, consisting of two frames of double walling pieces, each of them connected at the angles by uprights, and bound together with iron bolts The smaller frame being placed within the larger, the piles were driven between them into the sand This coffer-dam was fourteen feet square clear inside, and it was my intention to have constructed the Causeway in portions of fourteen feet square, according to the size of the dam, which was to have been shifted for each fresh portion, but I regret to say that, owing to the great force required to drive the piles, they split to such a degree, that, although shod and headed with iron, they were rendered perfectly useless for any second attempt, I was consequently obliged to have recourse to another expedient for a coffer-dam, which would serve to keep the sand from filling in from the outside as soon as taken out from the inside, and also one that could be placed in the bed of the river with expedition and facility

Accordingly split *tar* trees, ten feet in length, were driven down at one and a half feet apart into the bed to a depth of about nine feet, and a bamboo trellis work covered outside with gunny let down outside the piles, the sand was then taken out to the depth of six feet The success of this simple coffer dam, which was 155 × 16½ feet, was most complete

The concrete was formed in a dry state in the following proportions, under my personal supervision, viz —

Of unburnt Ghooting (nodules), two parts
Of half burnt Ghooting, one part

Of well burnt Ghooting, reduced to powder by a *dhenky*, one part
Of Soorkhee or Brick powder, one part

The ingredients were roughly mixed in a dry state and old gunny bags filled with it. These bags were carefully placed by hand round the sides of the coffer-dam on the first instance, and the centre closely packed with them afterwards, the water slaking the half burnt and powdered lime caused the material to swell, and the bags already tightly packed became so jammed together that they formed one compact mass of concrete. Six inches of hydraulic mortar was now placed over the bags independent of of that expended in filling in the unevenness of the surface. Over this again was built six inches of flat stone rubble masonry to afford an even bearing for the slabs, which were now placed close to each other, and imbedded in six inches of the finest hydraulic mortar well grouted in the joints. The whole was placed two feet below the natural surface of the sand, and the heads of the piles cut off flush with the Causeway so as to avoid any obstruction to the flood when it descended.

The work was well performed and presented one of the most solid masses of masonry I ever saw.

An experimental bag of dry material was by my direction immersed in water for ten days, at the expiration of which time it was taken out and was found to be so hard that an iron rod struck on it resounded as if it had been struck on stone.

Since the completion of the work it has been subjected to severe floods reaching from bank to bank, and I have much satisfaction in reporting that soundings, which were taken on the 6th instant, indicate that the experiment remains without injury, and, consequently, I am most sanguine as to its ultimate success.

I much regret that I have not been able to construct as great a length as was directed by the Military Board, but this has arisen entirely for want of means, at the same time, for the purpose of experiment, quite sufficient has been laid down, $165 \times 16\frac{1}{2} \times 4$ feet.

The expenditure actually incurred gives a rate of Rs 13-5-4 per running foot, but then in the former the running foot contains only thirty-nine cubic feet of work, in the latter sixty-six cubic feet, and at the same time being chiefly composed of stone instead of wholly of concrete, and altogether a superior construction, I do not consider the rate under the circumstances immoderate.

From the same to the same, dated 6th December, 1853

THE sand was removed from off the whole length, and the water having receded, the Causeway was left dry, so that I walked over and made a thorough examination of the whole work

The concrete in which the stones are imbedded has become perfectly hard, and as the first course of the structure, about two feet in depth, is composed of the same material put down in gunny bags, there can be no doubt of this having become in stability equal to a solid mass of stone, and which the present perfect state of the work corroborates, as no crack can be observed in any of the joints, nor is there any separation or settlement of the stones which would inevitably have followed partial settlement. The experiment may therefore be pronounced perfectly successful

The floods rose last rains higher than usual, the passage of the river was stopped on one occasion, and on several others the water extended from bank to bank, so that the experiment has stood as severe a test as it is ever likely to experience, and as it was placed where the flood will be most likely to bear upon it with a more than average severity (with reference to those portions that may be hereafter constructed, as they would not be subjected to the shifting of the channels, which has occurred in the present instance), I entertain not the smallest doubt of the feasibility of constructing a similar Causeway over the remaining portion of the sandy bed with success The maximum depth of water which flowed over the Causeway during the season may be estimated at about twenty feet, and it was covered from the end of June to the middle of November

I have the honor to submit an estimate, as requested, for a continuance of a Causeway of the same depth and breadth for one and a half miles

I avail myself of this opportunity of bringing to your notice the attention and ability with which Sergeant Bingham, Assistant Overseer, carried out my instructions

---

SPECIFICATION ATTACHED TO THE FINAL ESTIMATE

The distance from the western extremity or head of the Causeway to the point where the Baroon bank of the river rises above ordinary floods, and the metalled Grand Trunk Road again commences, is 11,450 feet. Of this 5,562 were completed up to December 1860, and about 1,000 feet

will, it is expected, be completed this season, leaving 4,888 feet to be hereafter completed

The line of the Causeway having been marked out, common jungle *bullah* piles will be driven in two parallel lines, at a distance of seventeen feet apart, to a depth of about fifteen feet, the sand having been excavated with shovels in the ordinary way Between these piles down to the water level, or a little below, bamboo frames with palm tree leaf mats are forced down behind, to prevent the sand from the sides slipping into the excavation The remainder of the sand below water level will be excavated to the required depth by means of the ordinary well sinker's jham,* worked from temporary stages on either side of the excavation

A layer of gunny bags, filled with concrete, composed of two parts Soane Shingle, one part Soorkee, and one part Kunkur Lime, are to be set as closely packed as possible over the whole bottom of the excavation

Over this a layer 2 feet 6 inches deep of rubble stone, set in concrete of the same proportions, as above specified, for the concrete set in the gunny bags, is to be placed, and on this the roadway formed of roughly cut stone slabs one foot thick, from one foot to one foot and six inches broad, and alternately nine and seven feet long, so as to break joint with each other, are to be carefully set, all irregularities of the lower surface of the slabs being carefully packed up with rubble stone, the joints made as narrow as possible without actually dressing the stone, and thoroughly filled up, grouted, and pointed with the best Kunkur Lime and Soorkee hydraulic mortar, any considerable roughness and irregularities of the surface are then to be chipped down and levelled by stone-cutters, no attempt being, however, made at anything approaching fine dressing the whole or any part of the surface of the stones, which would be objectionable, as it would cause the road to be dangerously slippery

In the flood of 1855, a small portion of the west end or head of the Causeway was undermined and destroyed † To prevent any danger of this again taking place, undersunk masonry blocks have been commenced to be sunk as a sort of curtain round the end, these blocks have already been sunk to a depth of about thirteen feet, they will be still further sunk by the

* So specified in original, but the jhams used were much smaller and set at a less angle to the pole than those used in well sinking —C J M

† This was supposed to be the case when this estimate was proposed, but the wells appear to have been filled up, and it is presumed were sunk to full depth before 1860, but there is no means of ascertaining this certainly.—C J M

usual well sinker's process to a depth of about twenty-five feet when the wells will be filled up with concrete and rubble stone

---

Memorandum by LIEUTENANT-COLONEL W MAXWELL, *Superintending Engineer, Behar Circle*

Dated 14*th July*, 1863

THE work is so simple and easy of execution that the Superintending Engineer has nothing to add to Captain Mead's description The Causeway is a perfect success, and not one foot of it has been in any way injured since he has had it under his charge—now some five and a half years The drawing sent will show precisely of what the Causeway is composed It is feared, however, that few rivers in India have close at hand such magnificent Sandstone Quarries as the Soane

---

No III

CANAL FALLS AND RAPIDS

[THE best forms to be given to Falls and Rapids on Canals of running water are questions which have long occupied the attention of Canal Engineers. In reference to the former the two chief questions are—1st, The best form to be given to the Fall itself, as regards economy of material and capacity of resisting the wear and tear of a large volume of water passing over it, 2nd, The best means of checking the accelerated velocity of the water above, caused by its passage over the fall For the first, the Ogee adopted on the Ganges Canal, and the vertical Fall, with or without a grating, as designed for the Baree Doab Canal, are the two forms in general use, for the second, the contraction of the lip of the fall, or the heading up of the water by a weir of masonry or planks, have been the expedients generally adopted

Rapids have been hitherto tried in the Baree Doab Canal only, and where boulders are plentiful, have been found efficient and economical

The following memoranda by one of our ablest Canal Officers will be found to bear on the above points The particular questions involved are by no means settled, and any Officer who will record his experience and observations will be doing a service to the profession —ED]

CAPT DYAS, *Director of Canals, Punjab, to Secy to Govt, N W P*
Dated 11th April, 1861

THE point you mention as to the increased velocity above Falls of the old pattern gave me something to think of some five or six years ago You may remember that in 1855, I think it was, I wrote to you about the

Ghoonna Falls on the Eastern Jumna Canal, at the same time I wrote to Baird Smith to find out if the thing had been observed on the Ganges Canal, but the bed had not then arrived at such a state as to force itself into notice, so there was not much thought about it

I dare say you know that the "perpendicular with grating" form which I adopted for Falls on the Baree Doab Canal avoids that difficulty altogether But we have one exception the Toghial Fall is built on the old plan with an Ogee

However I built it as a weir, its crest being 2 feet above the true bed of of the canal Looking over my old calculations now, I see that I had made one for diminishing the waterway over the Fall, but eventually I preferred to diminish the depth, and I still think it is in every way better Of course the natural tendency in the mind of an old canal man, is to object to build anything in the shape of a weir across a Canal on account of silt But practically it does not silt if the height of the weir is so calculated that the velocity of the water on the earthern channel is not checked The Ghoonna Fall to this day is to all intents and purposes a weir, and I do not suppose there has been any silting up above it since November, 1851, when I made a Sketch of it as shown (*Fig* 1, *Plate* VI)

I should recommend you not to reduce your waterway at Falls Your formula is not quite right, but it would give a tolerable approximation, sufficient to show that the waterway must be reduced *very much* if you desire to retain the full depth of water over the fall

I give you here an extract from some of my old calculations.

Discharge over Fall (complete) $= ml\left(h + \frac{v^2}{2g}\right)^{\frac{3}{2}} = ml\left(h + \frac{n^2d}{2gs}\right)^{\frac{3}{2}}$ and discharge in an open channel $= A\, n\, \left(\frac{d}{s}\right)^{\frac{1}{2}}$

In which equations—

$A =$ Sectional area of open channel

$d =$ Hydraulic mean depth of same

$s =$ Length of slope to fall of one in same

$v =$ Mean velocity of current in same

$h =$ Height of surface of water in same, above crest of fall

$l =$ Length of crest of fall

$m =$ A co-efficient determined by experiment varying from 2 5 to 3·5

$n =$ A co-efficient determined by experiments varying from 75 to 95.

The discharge in the open channel and that over the Fall are identical, hence we have—

$$ml \left[h + \frac{n^2 d}{2gs} \right]^{\frac{3}{2}} = A\ n \left[\frac{d}{s} \right]^{\frac{1}{2}}$$

from which we get—

$$l = \frac{1}{m} \frac{2\ Agns \sqrt{2dg\ (2ghs + n^2 d)}}{(2ghs + n^2 d)^2}$$

and if we put $g = 32\ 19083$, $m = 3$, and $n = 90$, we shall have—

$$l = \frac{02133\ As \sqrt{d\ (\ 008hs \times d)}}{(\ 008hs + d)^2}$$

You can easily compare the result given by this formula with your own Your formula is defective, in not making allowance for the velocity the current has before it arrives at the Fall It is the formula for discharge from a *reservoir*, no current Now for the weir, we have—

$$h = \left(\frac{A^2 dn^2}{m^2 l^2 s} \right)^{\frac{1}{3}} - \frac{dn_2}{2gs} \text{ and}$$

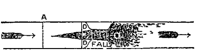
if g, m, and n, are as before

$$h = \left(\frac{900\ A^2 d}{l^2 s} \right)^{\frac{1}{3}} - 125\ 8122 \frac{d}{s}$$

Having thus got the value of h, deduct it from the depth of water in the channel, and you have the height to which the weir should be raised above the true bed of the canal

My reasons for advising you not to narrow at Falls (beyond the narrowing that of necessity takes place from building piers in the stream) are—

1st It is impossible for you to keep the velocity of the water in the channel above the Fall uniform in every part of its section The velocity at the section A might be all right, but at DD the water would be comparatively still, and I think your bed would cut in the centre, as per shading, making the Fall a weir after all



2nd When the water reached the foot of the Fall, it would be so heaped up by being confined to a narrow channel that the action would be very great

3rd These evils would arise even with only a full supply in If then at any time you wanted to raise your supply temporarily, they would be exaggerated

4th In case of repairs being required, you must shut off the Canal, for you have not room to shut off a portion only of the Fall, and to keep up the supply in the remainder

There is doubt that the first cost of the Fall would be much less, but I think its after expenses would be much greater than for a Fall of the full width

But I should recommend you to build a Perpendicular Fall of the full width whether you fix a grating (as we do) or not In my opinion the Grating Fall is the best yet known, and the next best is the Perpendicular Fall without Grating We have but one Ogee Fall on the Baree Doab Canal, and that one has given us more trouble in repairing it than all the rest together Indeed we have not had to touch the others, although we have had (last rains) a flood down the Canal that submerged them You can have no idea without seeing them how completely under control the water is by their means "*Divide et impera*," is their motto, and I think it is the true principle for dealing with unruly masses

As to comparative cost, the Perpendicular Falls are infinitely cheaper than Ogee Falls On the Baree Doab Canal the cost of a

						Rs
7-foot Fall,	100 feet	waterway, is,		-	-	46,000
8	"	80	"	-	-	37,000
7	"	50	"	-	-	20,000

We have one 17-foot Fall at the end of the Lahore Branch, where it tails into the Ravee It is built on wells in quicksand, and cost Rs 35,600 (waterway 40 feet) All the others above-mentioned are in sand, dry, no wells, nor arched floorings You must remember that our rates for work are very high, Rs 36 for arching, Rs 26 for superstructure, and Rs 21 for foundations (brick-work in mortar) You could work at about half these rates, I fancy, and the cost of the works would be proportionally diminished.

From CAPTAIN DYAS, *to Deputy Superintendent General of Irrigation, N W Provinces*

Dated 14th January, 1862.

I am very sorry I am not able to send along with this traces of our Falls of different kinds Here at any rate are the really important parts of them 8-foot Vertical Fall, No 17, at Furrudnuggur, built in 1854 (*Fig. 2, Plate* VI)

This Fall has answered admirably, never requires repair It had a stiff flood (3 feet higher than full supply) over it in 1860, when nearly all the Rapids were seriously damaged, but not a brick or boulder rather (for it is nearly all built of boulders in their natural state) moved

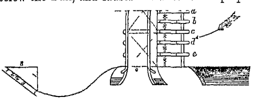
While looking at this Fall and experimenting on it, it struck me that the action of the falling water was concentrated along a very narrow strip, and in order to avoid this, I devised the next kind of Fall (*Fig* 3, *Plate* VI)

The soil was pure sand down to 17 feet below lower bed, when a stratum of clay was met with, and on it the deep foundations were brought up

This Fall acts capitally, two like this had the flood over them and never moved, while an Ogee Fall, a quarter of a mile higher up was much damaged, and is still giving much trouble

You can easily see how little action there can be on the bed, when you observe that the water falls over a space 18 *feet* wide here instead of 9 *inches* wide, as in the last example, and of course by altering the angle of the grating you can make the water fall over as large a surface as you please

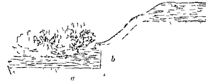
It is besides no mean advantage to do away with all risk of accident to boats or men going over the Falls, and to the Falls themselves from timber, &c , going over All the grass and rubbish too gets cleared out, for a Fall with a grating requires a man to be kept up to keep it clear There is no extra expense in this, as wherever there is a Fall, there is a lock, and men must be kept for the lock These Falls I have divided up into 10-feet bays, any one of which can be shut off separately for repairs while the water flows on through all the other bays It is sufficient, however, to be able to keep, say two-thirds of the Fall open and to shut off one-third This would, I think, be better for the action of the Fall, as the great number of piers with 10-feet bays diminishes the waterway below the Fall, and causes the water to heap up rather



Piers *a*, *b*, *d*, and *e*, are just long enough to carry the cross beams × on which the gratings rest

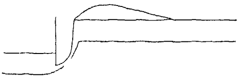
Pier *c* is a division, and runs right through the bridge, and is one of the bridge piers

Turnbull has now seen these falls, and is, I think, satisfied that they act well, I am perfectly satisfied with them myself



As to the Fall you sketched, I am sure you would gain your object of protecting the bottom *a*, but I think the corner *b* would run risk of continual damage I think it would be better to sink the *foot* of the *Ogee* below the *true* bed, and to finish with a reverse slope

But all these Falls, should be built like weirs, *i e*, with their sills raised above the Canal bed, in order to prevent acceleration of velocity in the neighbourhood of the Fall upstream, with the grating, no weir is required, but without it, a weir is necessary We have a 17-foot vertical Fall



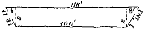
working well, which I showed to Turnbull In fact the higher they are the better, as the water falls more nearly truly vertical

---

Memo by CAPTAIN DYAS, *on a Plan of Rapid proposed by* CAPTAIN T G GLOVER, *Depy Supdt Genl of Irrigation, N W P, to be constructed on the line of the Western Jumna Canal, between Indree and Boodakheia*

Dated 2nd April, 1862

I shall first examine the details of waterway, velocity, and discharge



It is proposed to build the Rapid on a new channel of the section here shown, and of which—

	feet			feet
Bottom width	= 100	Hence	Sectional area	= 864
Depth of water	= 8		Perimeter of section	= 122 62
Side slopes	= 1 in 1		Hydraulic mean depth	= 7 046

The discharge which the Rapid must be capable of passing is 2,500 cubic feet per second	Hence		feet
		Mean velocity	= 2 894
		Height due to same	= 0 13
		Slope of bed 1 in 6817	= 0 77 per mile

The length of crest of Rapid is 108 feet, and hence the depth of opening (below surface of water in channel) required for the discharge of 2,500 cubic feet per second, taking into account the velocity of approach (2 894 feet per second) is 4 28 feet, and deducting this from the depth of water in the channel, (8 feet,) we have 3 72 feet as the height to which the crest of the Rapid should be raised above the true bed of the canal at that point, in order that there shall be no acceleration of the current in the channel above the Rapid In reply to questions about slope, Captain Glover informs me that with a view to reduce this acceleration, the last mile of the channel immediately above the Rapid is to be dug horizontal, no slope being given to the bed This arrangement takes off 0 77 foot from the calculated height of weir, leaving 3 feet as the actual height required The practical effect of raising the crest of the Rapid 3 feet, would of course be to add to its length (up-stream), and if the slope of the Rapid is kept, as per plan, at 1 in 10, the length of Rapid required to be added would be 30 feet

It would of course be possible to hold up the surface of the water above the Rapid by reducing the width of waterway instead of reducing its depth, and in this case the width of opening required, or the length of crest of Rapid would be 36 feet only This width of opening with the depth of 8 feet would pass the whole supply of 2,500 cubic feet per second, but the velocity in the channel above the opening would be very much accelerated, and the water would dig up the bed until it had excavated for itself a basin of sufficient depth to reduce the velocity to what the soil could stand without further abrasion On the 11th April last, in reply to a demi-official communication from Lieutenant-Colonel W E Morton, then Deputy Superintendent General of Irrigation, North-Western Provinces, and dated 4th April, 1861, I entered into this subject very fully, with reference to a Fall on the above principle proposed for erection on the Futtehghur Branch of the Ganges Canal, by J Parker, Esquire, the Executive Engineer of that Branch I shall be happy to forward a copy of that Memorandum if the original is not forthcoming in Captain Glover's office Now, as then, I do

not recommend the adoption of the above-mentioned method for reducing the acceleration of the water in the neighbourhood of a Fall or Rapid

The slope of the Rapid itself is 1 in 10, and the Rapid is 108 feet wide, without longitudinal walls or divisions From these data I make the depth of water flowing down the Rapid at full supply 1 4 foot, and its velocity 16 5 feet per second If the flooring of the Rapid were of brick-work instead of boulder-work, the depth of water would be 1 2 foot only, and its mean velocity 19 4 feet per second

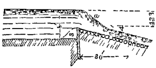
I now proceed to examine the details of design and construction of the Rapid It is a 10 foot Rapid, that is, the difference of level between crest and tail is 10 feet This difference is broken into two steps or descents, each descent consisting of a length of 70 feet at a slope of 1 in 10, a horizontal flooring to a basin of 20 feet, and a reverse slope of 20 feet at 1 in 10, a horizontal flooring or landing of 50 feet connects the two descents, and a horizontal flooring or tail of 50 feet at the end of the second descent completes the Rapid The object of the break in the descent as well as of the two 2-foot basins, and the reverse slopes is, I presume, to prevent undue acceleration in the current passing down the Rapid

The total length of the proposed Rapid measuring from the crest is 320 feet

The length of a 10-foot Rapid on the general plan of those built on the Baree Doab Canal (some of which are $9\frac{1}{2}$ feet) would be 275 feet, consisting of a slope of 1 in 15 for 150 feet, and a horizontal tail 125 feet long, being thus 45 feet shorter than the proposed Rapid, I would, however, adhere to the proposed plan as regards the arrangement of the slopes It is only by actual trial of new forms and combinations that we shall ever arrive at the best and cheapest arrangement for a Rapid I can answer for the good effects of the basins and reverse slopes Rapid No 3, ($8\frac{1}{4}$ feet,) on the Baree Doab Canal, has a 4-foot basin at its tail, Rapid No 13, ($9\frac{1}{2}$ feet,) is broken into four steps with 2-foot basins, and reverse slopes 25 feet long at the foot of each step, and Fall No 17, (vertical 8 feet,) has a 7-foot basin, and a reverse slope 50 feet long These basins and reverse slopes all act well

It should be noted that if (as I would recommend) the crest of the Rapid is raised 3 feet above the level of the canal bed, a length of 30 feet additional must be given to the Rapid, (its slope being 1 in 10,) or in other words the Rapid instead of being a 10-foot Rapid, will become

13-*foot Rapid*. I do not think it necessary that the additional fall

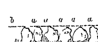


should be divided equally between the two steps into which the Rapid is broken; I think it may safely be added to the upper step, leaving the lower step as it is. I say this because I do not think that acceleration of the current as it passes down the Rapid need be feared. I have not observed any acceleration in practice; on the contrary, inasmuch as the depth of the current passing over the actual crest of the Rapid will be about $4\frac{1}{2}$ feet, and the depth of water in the Rapid itself will be but $1\frac{1}{2}$ foot, the great acceleration would appear to take place immediately after the passage over the crest, in the first 20 feet say, after which the current begins to assume the depth due to the slope of the Rapid—a sensible depression taking place at *a* in the Sketch.

This view is borne out by the result of a heavy flood which passed down the Baree Doab Canal in July, 1860. All the Rapids over which the flood passed were much damaged, in nearly every case the dry boulders being swept completely out of the first compartment formed by the Masonry Cross Walls, and deposited lower down on the slope and on the tail of the Rapid; at all events, it is evident that the flooring under the point *a* should be made as strong as possible.

And this leads to the consideration of the nature of the flooring of the Rapid. Having before me the results of the flood already spoken of, on the Rapids of the Baree Doab Canal, and having carefully examined those works in February last when the canal was dry, I have come to the conclusion that boulders are the proper material for the flooring of a Rapid, and that brick-work should not be used in contact with currents with such high velocities. It is true that the silt of the *Baree Doab Canal at the Rapids is heavier and sharper than that of* the Western Jumna Canal at the site of the proposed Rapid. Still I am convinced that brick-work, even of the very best, cannot stand the wear and tear for any length of time, and that stone should be used for all surfaces in contact with velocities exceeding say 10 feet per second. It may be observed also that the roughness of the boulder-work tends to check the velocity of the current passing down the Rapid, and that the reduction of velocity in the present instance would be about 3 feet per second. This is a decided advantage due to the use of boulders.

But I am of opinion not only that boulders should be used for flooring surface, to the exclusion of brick, but that the boulders should be grouted in with good hydraulic mortar and small pebbles or shingle. I do not think that dry boulder work is to be depended on for velocities higher than 15 feet per second, even when they weigh, as in the Baree Doab Canal Rapids, no less than 1 maund each, and are laid at a slope of 1 in 15. The slope of the proposed Rapid is considerably steeper than this, being 1 in 10, and Captain Glover informs me in reply to a question on the subject, that the average weight of the boulders he had intended using is, $17\frac{2}{3}$ seers only, that boulders up to 4 or 5 maunds each can be had, but of course with greater difficulty than the lighter ones, considering all this, I do not hesitate to say that dry boulder-work should not be used. I imagine that the extra cost of procuring very large boulders would go far to pay for the mortar required for grouting. There should be no attempt made to bring the surface of the boulder work up smooth, by filling in the spaces *aaa*. All that is necessary is to lay the boulders and to pack them so that their tops are pretty well in line as *bc*, any further filling in would stand a good chance of being washed out very soon, and if it remained its effect would be to increase the velocity of the current on the Rapid by diminishing the resistance presented to the water by the rough boulder-work, and of course an increase to the velocity means a decrease to the depth of water which in view of rafting timber, would be objectionable.



The Baree Doab Canal Rapids have tail walls of peculiar construction for the purpose of destroying back eddies, and of protecting the Canal banks below the Rapid from the direct action of the current (*Fig* 1, *Plate* VI.) These tail walls are intended to be so arranged that the heaviest action of water at the foot of the Rapid shall take place in the widest part AA, (the normal width of the Rapid being represented by BB,) and they incline towards each other from this point so as to direct the set of the stream well to the centre of the Canal, thus protecting the banks from the direct action of the current for a considerable distance. At the same time, as may be seen from the longitudinal section, the tail walls are not kept at their full height throughout, but beginning (a little below A, at the point where the curve ends) at the level of full supply only they gradually become lower and lower (slope 1 in 20) till they vanish

altogether at C where they are on the same level as the bed of the canal The triangular spaces ACD are filled in with boulders (dry) to the level of the top of the sloping tail wall, when the fully supply is running these tail walls are submerged and invisible, the Rapid appearing to the end just below AA

These tail walls have completely answered my expectations They do not check the "lap-lap," or ceaseless wave-like undulation of the water below the Rapid That is not their office, and indeed it would be difficult to check that movement, but they effectually do away with back eddies by keeping the current always in onward motion, exposing no abruptly terminating projection behind which an eddy can form, and at the same time they protect the banks by making that motion moderate in the neighbourhood of the banks

In case no such tail walls are given to the proposed Rapid, (none appear in the Plan,) I should recommend that the banks be faced with boulder work, *jamah* or piling, for a length on each side, of say 300 feet below the Rapid Some such protection will certainly be found necessary for the banks

There yet remains the consideration, what velocity of current will a Boulder Rapid stand without injury, as yet I cannot answer this question fully But the result of the flood of 1860, warrants my saying that a Boulder Rapid with a flooring composed of boulders not less than 1 maund in weight each, well packed *on end*, and at a slope of 1 in 15, will *not* stand a mean velocity of 17 4 feet per second I do not know with what velocity the Rapids began to be torn up, but I do know that not less than 5,000 cubic feet per second went down the canal with a depth of 7 feet on a slope of 1 in 1,250 For a short time, I believe, the flood rose to 9 feet, but to be on the safe side, I have based my calculations on 7 feet only It is pretty evident then that it is not advisable to try dry boulder-work at a slope of 1 in 10, each boulder weighing about $17\frac{5}{8}$ seers

To recapitulate—I recommend,

I That the flooring of the Rapid be produced up-stream 30 feet, and that its crest stand 3 feet above the canal bed like a weir

II That in the absence of tail walls, the banks be protected for a distance of 300 feet from the foot of the rapid

III That the boulders of which the flooring is composed be grouted in with good hydraulic mortar and small pebbles, and not laid in dry

No IV

BHORE GHAT INCLINE.—GREAT INDIAN PENINSULAR RAILWAY

[THE following details of this extraordinary work are taken from the Tabular Statements furnished to Government by the Chief Resident Engineer.—ED]

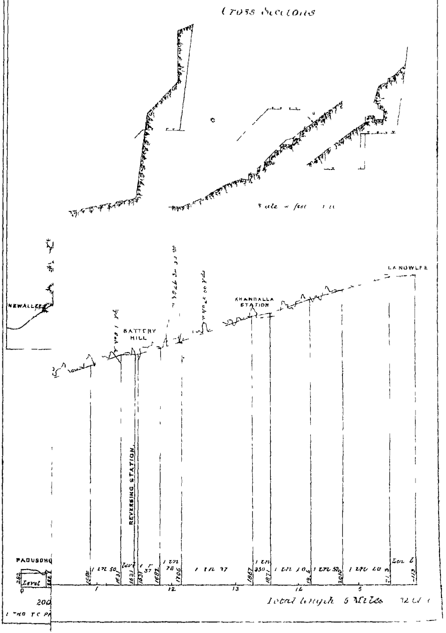
BHORE GHAT INCLINE

Table of Gradient and Level portions Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point.	Length		Rate of Inclination	Miles from fixed point.	Length		Rate of Inclination
	Chains.	Links			Chains	Links.	
	32	84	Level	10			
	175	12	1 in 150		39	15	1 in 50 03
2					20	50	Level (Reversing Station)
	405	50	1 in 40				
7				11			
	10	14	Level		28	25	1 in 37
	91	36	1 in 42		27	45	1 in 75
8				12			
	30	83	1 in 43 164		90	26	1 in 37
9				13			
	125	66	1 in 40		7	79	1 in 380

Gradients all ascending Total difference of level between foot of incline and end of last Gradient, 1586 67 feet Total length of incline, 13 miles 44 35 chains Severest Gradient is 1 in 37, for a length of 1 mile 10 26 chains

THE BHOPE GHAT INCLINE



Bhore Ghat Incline

Table of Curves and Straight portions Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length		Radius	Side to which it bends
	Miles	Chains	Chains	
		6 31	40 00	Curve to left
		50 00		Straight
		38 00	30 00	Curve to right
1				
		29 00	30 00	Curve to left
		13 00	30 00	Curve to right
		25 00	30 00	Curve to left
		47 76		Straight
2				
		57 24	30 00	Curve to left
3				
		19 71		Straight
		30 31	28 00	Curve to right
		9 75		Straight
4				
		14 25	40 00	Curve to right
		8 19		Straight
		28 14	30 00	Curve to left
		25 34	28 00	Curve to right
		19 00	26 00	Curve to right
5				
		5 00		Straight
		7 00	33 00	Curve to right
		10 00	62 00	Curve to right
		17 94	80 00	Curve to left
		35 86		Straight
6				
		35 23	48 00	Curve to left
		36 00	48 00	Curve to right
7				
		17 25	80 00	Curve to left
		8 00	64 00	Curve to left

Bhore Ghat Incline

Table of Curves and Straight portions *(Continued)* Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length		Radius	Side to which it bends
	Miles	Chains	Chains	
		22 50	30 00	Curve to right
		17 50	20 00	Curve to left
		10 50	30 00	Curve to right
		32 50		Straight
8				
		12 00	31 50	Curve to right
		10 00	43 50	Curve to right
		1 00		Straight
		8 00	99 00	Curve to right
		10 60	21 00	Curve to left
		9 20		Straight
9				
		6 00	20 00	Curve to right
		2 00	69 00	Curve to right.
		5 00		Straight
		5 00	20 00	Curve to right
		3 00	25 00	Curve to right
		10 00	25 50	Curve to right
		21 00	27 50	Curve to left
		64 55		Straight
10				
		18 00	61 00	Curve to right
		3 00		Straight
		10 00	54 50	Curve to left
		6 00	21 00	Curve to left
		3 00		Straight
		7 71	50 00	Curve to right
11				
		12 00	30 00	Curve to right
		12 50		Straight
		8 53		Straight [Station
		9 67	22 00	Curve to right Reversing

Bhore Ghat Incline

Table of Curves and Straight portions *(Continued)* Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length		Radius	Side to which it bends
	Miles	Chains	Chains	
		8 00	20 00 24 00	Curve to left { Reversing Station
		8 00		Straight
		3 25	30 00	Curve to right
		7 75	30 00	Curve to left
		9 00	20 00	Curve to right
		3 00	25 00	Curve to right
		2 00	17 00	Curve to right
		23 00	15 00	Curve to right
12				
		12 00		Straight
		7 50	51 50	Curve to left
		5 00	80 00	Curve to right
		12 50		Straight
		18 00	80 00	Curve to right
		9 00		Straight
		6 00	20 00	Curve to left
		4 00		Straight
13				
		23 92	30 00	Curve to left

Sharpest curve has a radius of 15 chains, and is 23 chains long, on an incline of 1 in 75.

BHORE GHAT INCLINE

Table of Cuttings and Embankments Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length Chains	Greatest height or depth to formation—level on centre of line. Feet	Cubical content Yards	Remarks
	8 10	28	24,534	
	22 10	46	176,538	Retaining walls built of rubble masonry, with a batter of 2 to 3 inches per foot
	25 30	48	155,301	
1				
	7 20	46	55,767	
	13 80	73	195,288	
	8 10	58	96,785	Retaining wall 3 60 chains long
2				
	2 20	13	1,723	
	23 80	74	364,305	
	8 00	62	124,836	
	1 90	56	6,418	
3				
	1 00	36	811	
	80 1 40 1 30	45	9,632	Retaining wall 1 50 chains long
	9 90	28	39,463	Retaining wall 4 80 chains long

BHORE GHAT INCLINE

Table of Cuttings and Embankments *(Continued)* Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length Chains	Greatest height or depth on formation—level on centre of line Feet	Cubical content Yards	Remarks
4	11 80	37	76,523	Retaining wall 10 20 chains long
	9 90	66	190,192	Retaining wall 2 50 chains long
	1 30	42	2,769	
5				
	3 50	11	5,766	
	1 50	2	187	
	60	1	33	
	70	5	193	
	80	9	1,580	
	90	16	1,436	
6				
	70	6	487	
	2 30	11	1,404	
	7 10	13	8,051	
	2 60	11	1,741	
	18 20	36	82,522	
	1 10	8	593	
	19 50	23	29,324	Retaining wall 3 50 chains long
7				
			5,509	Retaining wall 14 00 chains long
	4 20	13	6,415	Retaining wall 6 00 chains long

Bhore Ghat Incline

Table of Cuttings and Embankments *(Continued)* Fixed point, foot of Ghât Incline, near Padusdhurce

Miles from fixed point	Length Chains	Greatest height or depth on formation—level on centre of line Feet	Cubical content Yards	Remarks
	2 80	23	22,797	
	2 10	44	19,903	
	1 30	8	2,440	Retaining wall 1 20 chains long
			577	Retaining wall { 0 60, 1 00, 0 80 } chains long
	70	9	1,966	Retaining wall 0 60 chains long
8				
	2 98	20	6,986	Retaining wall 3 70 chains long
	5 40	26	14,705	Retaining wall 5 30 chains long
	11 60	46	97,633	
	13 10	38	15,172	Retaining wall 15 00 chains long
9				
	15 90	53	250,940	Retaining wall 3 70 chains long
10				
	5 20	16	21,870	Retaining wall 6 40 chains long
	1 30	11	3,396	Retaining wall 5 30 chains long
	90	5	550	Retaining wall 1 80 chains long
	4 50	27	15,221	
	15 80	21	32,215	
	9 00	18	17,809	Retaining wall 9 60 chains long

BHORE GHAT INCLINE

Table of Cuttings and Embankments *(Continued)* Fixed point, foot of Ghât Incline, near Padusdhuree

Miles from fixed point	Length Chains	Greatest height or depth on formation—level on centre of line Feet	Cubical content Yards	Remarks
11				
			76	
	2 00	9	894	
			351	
	50	4	428	
		41	16,833	Retaining wall 14 20 chains long
	6 60	24	15,081	Retaining wall in cutting No 70, 18 50 chains long
		-	...	
12				
	2 70	25	47,261	
				Retaining wall in cutting No 73, 1 20 chains long
			775	Retaining wall in cutting No 75, chains long
	2 30	28	5,389	Retaining wall 3 50 chains long
	5 80	33	11,690	Retaining wall in cutting No 77, $\left\{\begin{array}{l}3{\cdot}40\\ 2\ 20\\ 1\ 80\end{array}\right.$ chains long Retaining wall in embankment No 70, 3 50 chains long
	5 90	4	3,158	Khandalla Tank Retaining wall 7 00 chains long
13				
	4 90	2	380	

Side slopes of Cuttings and Embankments are all $1\frac{1}{2}$ to 1. Deepest or highest Cutting or Embankment, 74 feet. Nature of material not given.

There are three Masonry arched Bridges, carrying Public Roads over or under the Railway. The largest having one span of 60 feet.

There are twenty-one Masonry arched Bridges and Viaducts, carrying the Railway over Rivers, Water-courses, &c., the two largest having each eight semi-circular arches of 50 feet span.

The greatest height from the bottom of the water-course to the level of the rails is 143 feet—the general width between parapets 29 feet.

There are two level crossings.

There are twenty-six Tunnels, of a total length of 3,987 yards, of which 412 yards are artificially lined with stone.

There are ninety Culverts varying from 2 to 6 feet span. The rails are of the usual double headed pattern, and weigh 85 lbs. to the yard; they are fixed in chairs which are laid on transverse sleepers of teak wood, 9′ 9″ × 10″ × 5″. The rail joints are made with fishing pieces, laid in iron saddles, which are bolted to timber longitudinal bearers properly secured to the transverse sleepers.

(Signed) R. W. GRAHAM,
Chief Resident Engineer.

No V

IRRIGATION AND DRAINAGE IN THE DEYRAH DHOON.

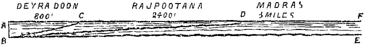
Memorandum on Improvements in the Irrigation of the Deyrah Dhoon, and Remarks on the Drainage of the Eastern portion of the Valley. By R E Forrest, Esq, *Superintendent, Dhoon Canals*

The want of water in the Deyrah Dhoon is so very great, that any scheme to increase or render permanent the supply seems to carry a recommendation in itself But it is necessary to examine carefully into the merits of each scheme if only to determine its value in relation to other schemes Inferior schemes are carried out at the expense of superior ones. They withdraw time, money, and attention from them Of the inferior kind appear to me to be the schemes for the construction of Tanks and Anicuts in the Dhoon, and as they have so often been pressed upon the attention of the Government, with the evil effects above noted, I think it would be profitable to try and settle the question of their utility once for all, if possible, and so cause them to be laid aside

Tanks and Reservoirs have been found to answer very well in other parts of India, and it seems to have been concluded from this that they must answer very well in the Dhoon also The difference in natural features does not seem to have been taken into consideration Dams have been thrown across the Cauvery and the Kistna, and great irrigation has taken place from the dammed up waters But it is a different matter to place a masonry dam in them, and to try to place a dam in the Jumna or the Ganges in the Himalayas They have a broad shallow section and a gentle slope, the Ganges and Jumna run in narrow deep channels and down a steep decline They are alluvial rivers, these hill torrents So with regard to a Tank Em-

bankment In the level plains of Madras or Rajpootana such an embankment backs the water over a wide surface of country, in the Dhoon it could throw it back but to a short distance, as it would have to back up a steep incline This consideration of the difference of slope shows so strikingly the difference of the value of such works in other parts of the country, and in the Dhoon, that I will reduce the result to figures

In Madras the slope of the country is about 4 feet per mile, in Rajpootanah where the lakes are about 6 inches per 100, in the Dhoon, 1 5 feet per 100 feet.



The diagram shows the effect that would be produced by the erection of a dam 12 feet high in each of these places The strikingly different results are at once visible to the eye The perpendicular line AB representing the Dam, the triangle ABC shows the section of the tank it would produce in the Deyrah Dhoon, the triangle ABD, the sections of the tank it would form in Rajpootana, and the trapezium ABEF shows about one-third the section of the tank it would form in Madras. Let us assume the length of the dam to be 100 feet, then we have

$$5{,}280 \times 3 = 15{,}840 \times 100 \times 12 \times \tfrac{1}{2} = 95{,}04{,}000$$
$$2{,}400 \times 100 \times 12 \times \tfrac{1}{2} = 14{,}40{,}000$$
$$800 \times 100 \times 12 \times \tfrac{1}{2} = 4{,}80{,}000$$

as the cubic contents of the tanks produced by the same length and height of embankment in Madras, Rajpootana, and the Dhoon, respectively In Rajpootana it would store up about three times as much, and in Madras about twenty times as much, as in the Dhoon

W Jameson, Esquire, Superintendent of Botanical Gardens in the N. W Provinces, says in his report of the 12th May, 1862, which has called forth this present Memorandum, that "even to the great canals, Anicuts made in the interior of the Himalayas on the course of the great rivers would be of vast advantage, as by them the full supply of water could always be maintained," and the Ganges and the Jumna are the rivers alluded to Now the slope of the Jumna in the interior of the Himalayas is about 3 feet per 100 feet Its breadth in the Dhoon after leaving the hills is about 200 feet Say then that in the interior the

average breadth of a reservoir formed by an Anicut is 300 feet A dam 20 feet high would hold up $670 \times 300 \times 20 \times \frac{1}{2} = 20,10,000$ cubic feet, a large looking amount, but which is really only half a day's supply of the Beejapore canal, which carries 50 cubic feet per second As for the large canals, to give the Eastern Jumna Canal one day's supply at its lowest, would require a dam 515 feet high—a formidable work And even if I reduce the above calculation by a half, to make allowance for having assumed too great a slope or too narrow a width, for a week's supply of the Eastern Jumna Canal, we should require a dam 1,800 feet high I am afraid such a work would stand about as long and terminate with the same results as the great natural Anicut which Dr Jameson describes as having formed on the river Indus, it held up that river for about a month, and then gave way and destroyed one or two large stations in the plains

I have thus discussed the *comparative* value of Tank Irrigation in different parts of the country, and shown that the Dhoon does not take a high place in that comparison It will now be necessary to discuss its *positive* value in the Dhoon itself

In a discussion of this question, it ought to be mentioned that Sir Proby Cautley was favorable to the construction of tanks in the Dhoon, and *that* being a fact of much weight on that side of the question, it is necessary to give his calculations at length When recommending the putting in order of certain old tanks in the Dhoon, Col Cautley forwarded the following calculations to the Military Board, with his letter of 4th November, 1840 —

KAOLI TANK

Mean length, ...	360 feet
Ditto breadth, .	200 „
Level of water to be raised,	7 „

$\frac{500 \times 360}{2} = 430 \times 200 \times 7 = 6,02,000$ cubic feet

$\frac{6,02,000}{1,089} = 553$ pucka beegahs

27,225 square feet in a pucka beegah One cubic foot of water will irrigate 25 square feet of land, *ergo*, for each beegah 1,089 cubic feet of water are wanted, so that 1,089 being made a divisor to the total number of cubic feet of water in the tank, gives the number of beegahs to be irrigated. But, when in the year 1859, then too, I believe, chiefly at the recommendation of Dr. Jameson, a project was taken up for the placing of

a dam or embankment across the Dhakia ravine, situated just above the Kaolagu Tea gardens, and a plan and estimate made out for it by Lieutenant Powys, Superintendent, Dhoon Canals, Colonel Baird Smith, then Superintendent General of Irrigation, made the following remarks on it —

" In accordance with the details of the project submitted by you, the basin which would be formed by the Dhakia Bund would have the following dimensions —

" Length about 1,200 feet, mean breadth about 250 feet, depth of water say 16 feet, the height of bund being 20 feet The cubic contents of water would accordingly be 48,00,000 cubic feet, which by the best data I have, would if used in the irrigation of Rubbee crops be sufficient for only 240 beegahs, and if for Khureef crops, less than half that area Further, if applied to increase the volume of the Beejapore canal, it would give an increased supply of 10 cubic feet per second for about 5 days, or of 20 cubic feet for $2\frac{1}{2}$ days during the season " Upon these calculations the project was abandoned

In the above calculations by Colonel Cautley and Colonel Smith, it will be observed that the latter with about 80 times *more* water calculates on *less* irrigation by about a half, but as Colonel Cautley calculated only for one watering and Colonel Smith most likely for full irrigation, or three waterings, this would diminish the difference between them by a third, and make the comparison—

Colonel Cautley with

6,02,000 cubic feet, irrigates	-	553 beegahs, partially
Ditto ditto	-	184 „ completely

Colonel Smith with

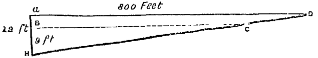
48,00,000 cubic feet, irrigates	-	240 beegahs completely
i. e, for the irrigation of one beegah		
Colonel Cautley allows	-	3,272 cubic feet
Colonel Smith allows	-	20,000 „

Colonel Smith's calculation was undoubtedly the true one. Colonel Cautley is much in excess The very large quantity of irrigation he gets from a cubic foot of water arises from his taking $\frac{1}{25}$ foot, or less than half an inch as the depth of water for one watering This would scarcely wet the surface of the ground The correct amount would be more nearly 4 inches above, and 2 inches below, the surface of the ground The element of time was also left out of his calculation He makes no allowance for absorption or evaporation To make " 1,089

cubic feet a divisor to the contents of the tank" is to suppose that the contents of the tank can be spread over the surface of the fields in an instant of time It is the omission of this consideration, it seems to me, which constitutes the chief error in all calculations relating to tank irrigation, and which makes the actual results so very different from the figured calculations

Being able to judge from the above calculations what items of account were omitted from them, I will now try to make an approximate independent calculation as to the irrigating power of a tank in the Dhoon It is no use making such a calculation for the Khureef season, the requirement of the water being too great then to make it profitable to supply it in the Dhoon from tanks, and because it is in that season chiefly that the tanks will be filled by the rain

For the Rubbee crop then we may take the irrigation season to extend over 130 days Three waterings are required, and for each watering a depth of 4 inches For the three waterings we require a depth of 1 foot, therefore, the area of an acre being 43,560 square feet, this gives us 43,560 cubic feet as the quantity required for the irrigation of one acre of land, or 43,56,000 cubic feet for 100 acres The above is however, subject to a deduction on account of absorption and evaporation But, as it will be more convenient, we will make this deduction from the contents of the tank Sir A Cotton calculates this loss at one-quarter inch per diem in Madras Say it is 1 foot per month, then during the three months over which the season extends there will be a loss of 3 feet in depth The depth of tank embankment in the Dhoon would be about 12 feet The slope of the country being 1 5 foot per 100 feet, this would give a section of tank as in the diagram, the area of which would be



4,800 cubic feet But taking in the loss by evaporation as above, viz, 3 feet, we have to make a deduction as follows —

Contents of AHD equal 4,800 cubic feet,
Deduction ABCD „ 2,100 „
Which leaves 2,700 cubic feet as the effective irrigating power of the tank

For the irrigation of 100 acres we require 43,66,000 cubic feet, divi-

ding this by 2,700 we have 1,613 feet as the required length of the tank embankment Taking it at 1,600 feet, the cost of the earthwork of the embankment would be Rs 2,000 To this would have to be added at least Rs 500 for masonry outlets, escapes, &c , making the whole cost Rs 2,500 For the irrigation of the 100 acres the return at the present rate for Rubbee irrigation in the Dhoon would be only Rs 50, and the rates would have to be more than doubled to make it pay 5 per cent on the outlay

Even the above result errs, I think, on the side of being too favorable to tanks It is founded on suppositions, which, however anxiously taken, are more or less subject to error When we come to deduce results from actual existing tank irrigation we find the result still more unfavorable The Chumbrumbaukum tank in Madras contains 3,000,000,000 cubic feet, and irrigates 10,000 acres of rice, which gives 300,000 cubic feet as the amount required to irrigate one acre The Cauvery Pauk tank in the same manner gives 2,86,000 cubic feet as the amount required for one acre These amounts are about four times what my calculation gives The irrigation from these tanks is rice irrigation, and would require a larger amount of water, and in such wide-spread sheets of water the loss from evaporation would also be much greater But at all events the above amounts are actual amounts, and not theoretical ones

In the same manner if the result of the tanks in Rajpootana be looked at, it will be found that they irrigate but small extents of land compared to the volume of water they store up I have, unfortunately, mislaid my memoranda on these tanks and cannot give figured statements * That they have proved so successful arises from the fact that they produce oasis in the deserts where they are constructed, and any irrigation and cultivation is better than none, and that they are constructed in very favorable situations, in the midst of low chains of hills , it is only necessary to back up narrow gorges, and the sides of the hills themselves form solid embankments without any cost They also supply the only good drinking water , and I am not arguing against the utility of tanks in favorable positions, but that there may be positions unfavorable to them, of which the Dhoon is one

Again, I have calculated the cost of the tank to contain 43,56,000 cubic feet, as Rs 2,500

The cost of the Dhakra ravine reservoir which was to contain 48,00,000

* See note at the end —[ED]

cubic feet, was Rs 2,617 by estimate, without masonry escapes, &c My estimate is not therefore a high one Taking it as an approximation, not very far from the truth, we have Rs 6 per 10,000 cubic feet as the cost of tank water in the Dhoon

The Beejapore canal supplies on an average 40 cubic feet per second through the year This would give 1,26,14,40,000 cubic feet as the total supply during the year Its capital, cost in round numbers, is Rs 40,000 This gives only 5 annas per 10,000 cubic feet This canal is no doubt the most favorably situated in the Dhoon But taking even the worst, the Kutha Putthur canal, the capital sunk in which has been Rs 2,15,000, (about twice as much at it ought to have been,) we have only Rs 1-8-0 as the cost of 10,000 cubic feet of water, one-fourth the cost of the same amount by tank storage

My opinion, founded on the above considerations and calculations, is not therefore in favor of the construction of tanks and reservoirs in the Dhoon, and I am glad to find that opinion supported by the opinion of an officer of such weight and experience as Mr Fleetwood Williams He draws attention in his memorandum to the numerous dry tanks to be met with in every part of the Dhoon Showing how ineffectual were the attempts to supply the want of water by that method *

That want might be almost sufficiently met, it seems to me—1st, By taking up all the water available throughout the year in the rivers and mountain torrents, 2nd, By utilizing that water to the utmost extent when obtained

These objects are to be obtained, with regard to the first By placing the heads of the canals as high up in the hills as possible, 2nd, By taking advantage of the superabundant supply of water in the rains

And for the second point, by having every channel, however small, along which water runs, lined with boulder masonry

I—The only canal in the Dhoon, which derives its supply from a perennial stream is the Kutha Puthur canal, which is taken off from the Jumna river The others are taken off from mountain torrents, which, while always retaining a supply in their upper portions in the gorges of the hills, are dry for six months of the year in that portion of

* But numerous traces of former canals exist all over the country which certainly do not show that canal irrigation was a fruitless labor There is no doubt that in many districts, canals and tanks have fallen into decay, either from the disturbed state of the country prior to British rule, or in many instances from the original defective construction of the works, owing to their unscientific design —[ED]

their course which runs through the Dhoon. It is, indeed, somewhat extraordinary to see how soon this absorption takes place; what is a large stream in the hills, scarcely enters on its valley channel, in any other months than during the rains, but it disappears altogether. The higher up in the hills, therefore, we place the heads of our canals, the larger and more constant will be the supply. The canal is doubtless thereby exposed to the dangers of a longer hill line, but this can be met by careful construction. The fall of the beds of these hill torrents is very great, and by going higher up we obtain more slope for the canal and thus can give it a narrower section. This diminishes the danger of its running along a hill side. On the Jhakkun canal, Lieutenant Walker, by carrying the site of the head up 4,000 feet, was enabled, while obtaining a constant supply of water, to reduce the breadth of the channel from 10 feet, to 3.5 feet, being able to make the slope 6 inches per 100 feet instead of 3 inches as originally intended. In rising up from the deep beds of these mountain gorges, all canals will have to run for longer or shorter distances along one of its steep sides. By going higher up we are also enabled to turn the heads of the drainage ravines that cross the country. Again, the higher up a canal head is, the sooner will it be able to emerge on the culturable table land, a very great advantage when the extent of land is so limited as it is in the Dhoon.

By obtaining a command of fall, we can make all the channels so narrow as to admit of the use of boulder masonry at very nearly the same cost as it would be for a broad earthen channel, thus preventing all loss by absorption and diminishing the cost of repairs.

On the Kutha Puthur canal, the great error, it seems to me, was in placing the head so low. This has brought about a masonry channel 10 feet wide and 4 feet deep, when a channel 5 feet wide and 2 feet deep would have sufficed, by making use of the additional fall, which could so easily have been obtained. Hence it has resulted that the canal crosses deep ravines by means of heavy embankments and lofty aqueducts, which are always giving way. The heads of all these ravines could have been turned. And no great additional safety has been obtained for the masonry channel which hangs for 4 miles over the side of a steep bank as dangerous as a hill side. And by the head being so low down the stream, no water can be given to large tracts of land, such as that about Domayt and to the north of Kadarpore.

The head of the Beejapore canal is well placed, but here there was another error by which also sufficient advantage is not often taken of the supply of water at hand The channel was not made large enough For a great number of years the water had been sent down flush with the tops of the side walls By simply raising these and increasing the supply of water, a most remarkable increase of irrigation was obtained

On the Kalunga canal it would have been a very fine scheme to have acted on the above principles, and placing the head of the canal well up the valley of the Soane, to have brought the channel from there on to the Sunsadharah valley, and taking in the water there to have carried the united streams on to the high land at Nagul, and then come round to Raipore along the west face of the Kalunga hill The head of the Jhakkun canal is placed high enough The head of the Raepore canal is being carried higher up

There is another way in which sufficient advantage is not taken of the water at command in the Dhoon , and this is a point worthy of much consideration During the rains there is a superabundant supply of water in all these hill torrents This is all allowed to run to waste Why should not this be utilized by means of *one season* Canals, if I may so call them? On the canals below the hills, as the Ganges canal, the demand for water is chiefly during the Rubbee season Hence a canal is designed to carry very nearly the largest supply that can be obtained then But in the Dhoon, where one of the staple products is rice, there is a great demand for water during the Khureef season The sections of the canals have generally been designed to carry only the largest Rubbee supply, and not a Khureef supply The calculation has generally been made from the supply of water in the month of November, and with no reference to what is likely to be in August The wheat grown in the Dhoon is of a very inferior, the rice of a very superior, quality If by the increased supply of water we could cause more of the latter to be grown, the capability of the land would be developed in the most favorable direction These Khureef canals might be taken off from many streams which are altogether dry during the winter and hot months, and only full during the rains They also might be added on as supplementary channels to already existing canals taken off from perennial streams, but in which the supply is ten times greater in the rains than it is during the winter

Thus, on the Beejapore canal, another channel might with great advantage be constructed along the bank of the ravine opposite to that along which the present channel runs. It will be seen from the accompanying sketch map that the present channel runs along the left bank of the Tonse ravine. This bank was chosen originally, because it joins on at once to the high land which the canal is meant to irrigate. The channel to be constructed on the opposite bank would have to cross the ravine, in order to gain the high land. But to enable it to do this would require an aqueduct of no wider span than 30 to 50 feet. The existing channel enters on the high land at Dhakia; the proposed channel would enter on the high land about Kaolagir. I have traced its probable course on the sketch map. That such a supplementary channel would be of service, nay, is absolutely needed, the following considerations will show:—

BEEJAPORE CANAL

Lands irrigated		Cultivated but not irrigated for want of water	Total lands culturable and irrigable
Rubbee	Khureef		
4,574	2,188	Beegahs 12,877	Beegahs 13,997
6,762 beegahs			

The above table shows how small a portion of the land that *can* be irrigated by the Beejapore canal *is* irrigated by it. That it is not irrigated, is for want of water. An additional supply cannot be given in the Rubbee. But why should it not be given in the Khureef? From the above table it will be observed that the Khureef irrigation is only half that of the Rubbee, (though this is a larger proportion than it is in the plains, on the Ganges canal for instance, the Khureef irrigation being about a fourth or a fifth only of the Rubbee irrigation,) but this is owing to the larger quantity of water* required for rice cultivation, and the full supply being only a Rubbee supply. The rice also is a valuable and expensive crop, and is only undertaken when there is a certainty of a con-

* Not quite so, but to the people having yet to learn the valuable Khureef crops, as sugar, rice and indigo, that can be grown by canal water. These crops are gradually increasing, and I have little doubt that in course of time the Khureef will exceed the Rubbee on the Ganges Canal.

stant supply of water. From the detailed statement that accompanies this memorandum, it will be seen that the chief portion of the lands that are cultivated, but not irrigated for want of water, lies in the Hopetown Grant. There then are, in round numbers, 4,300 beegahs in this condition, and in the whole of this large estate there are only about 200 beegahs irrigated. The supplementary channel would at once bring this large track under irrigation. If this additional irrigation gave only additional revenue of Rs. 500, this would allow of Rs. 10,000 being spent on the supplementary channel, for which it ought certainly to be constructed.

The extension of the valuable and locally suitable crop of rice instead of wheat would be an advantage in itself. It would also be of advantage in another way. From there not being so great a demand on the water during the Rubbee for wheat, it could be given to the tea, which is then most in want of it.

In the same manner channels of Khureef irrigation might be taken off to the right and left from the Rajpore canal.

II. To make the most use of the water, when we have got it. This is to be done by making every channel, along which water runs, of masonry, so as to prevent all loss by absorption and evaporation, both of which, and the former especially, are causes of great loss in the Dhoon. The whole of the channel of the Beejapore canal is being gradually lined with masonry. On the Rajpore canal the remaining lower portion, and on the Kalunga canal the Muamoolla branch might also be lined with masonry. On the Kutha Puthur, from the small slope, the channel is too wide to admit of its being profitably lined with masonry, but the different small channels might be so lined. But not only ought all the channels connected with the canals, down to the minutest, to be of masonry, but the smallest village cuts ought to be so if possible. Every inch of water is of use, and ought to be saved if possible. Some of the Zemindars have already, of themselves, made such masonry channels leading to their fields. The cost of such ducts is only about Rs. 200 per mile. It is in the minute sub-division of the water by the village Kools that the chief loss of water takes place. To the large Tea Companies, who have so heavy a stake in the land, and whose prosperity depends so much on the supply of water, such a measure has perhaps only to be proposed to be carried out.

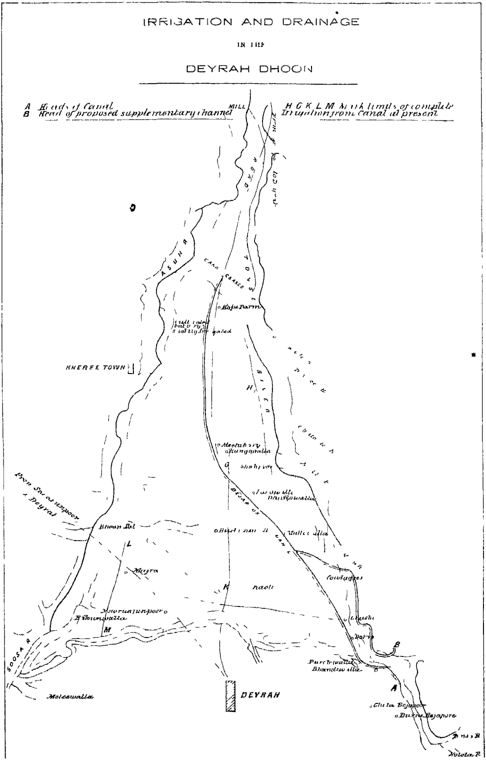
These are the general principles, it seems to me, on which the improvement of the Irrigation in the Dhoon can be best carried out

I have now to offer a few remarks on the subject of the Drainage of the Eastern Dhoon

This subject is one of the greatest interest to all concerned in the prosperity of the Dhoon, as on it depends the reclaiming and making culturable some thousands of acres of the richest land in the valley, and of taking away the drawback of unhealthiness from the best natural means of entrance into the valley from the plain, the Hurdwar road It is of special interest to the canal officer, as it is likely to have an important bearing on the future of the Jhakkun canal That canal runs through almost the extreme Eastern part of the Dhoon, and if that part continues, as it has hitherto been, to be a home of terror to all settlers, the interests of the canal will suffer

The chief marshes in the Eastern Dhoon are the Goosemwalla marsh and the Jogewalla marsh , the former, the larger in extent, and the first worthy of treatment The only reason that these marshes have not been drained is, that no measures have been taken to do so Captain William Brown, when surveying the Dhoon for the Revenue Survey, remarked on them, "low marshy ground, *easily drainable.*"

There is a marked difference in the characters of the Eastern Dhoon and the Western Dhoon The former has a slope of about 38 feet per mile towards the Ganges, the latter has a slope of only 28 feet per mile towards the Jumna. The consequence is, that in the Western Dhoon the drainage lines running down the sharp Himalayan slopes, have a less longitudinal slope to act on them in turning them from this course, and they consequently run straight down the Himalayan slope to the great drainage line, the Tonse, at its foot, and then waters are passed off without let or hindrance to the Jumna In the Eastern Dhoon, on the contrary, the sharp longitudinal slope deflects the Himalayan drainage lines from their straight course, and taking them in independent lines to the Ganges, scatters more water over the country. And the most important difference is, that the great mountain wall of Budraj and Mussoorie cuts off the Western Dhoon from the drainage of the interior, while in the Eastern Dhoon the great drainage lines, as the Tonse river and the Jhakkun river, from far in the interior throw large volumes of water into it, and produce a greater saturation of the land Thus it is that the marshes in


IRRIGATION AND DRAINAGE
IN THE
DEYRAH DHOON
A Heads of Canal
B Head of proposed supplementary channel
H G K L M limits of complete Irrigation from Canal at present
MILL
ASUNA
TOLSE
KHEREE TOWN
Shahpoor
Bheem Tal
Magra
DEYRAH
Molcewalla
Koulagher
Ajabpore
Birn
SOOSA R.
Nolota R.
H
G
K
L
M
A
B

the Eastern part of the valley have come to form its chief characteristic, while they never existed to any great extent in the Western Dhoon.

At both ends of the valley, however, the descent from the high land to the beds of the rivers is made by a similar series of steppes.

The above would be a section for about three or four miles of the Dhoon land on the banks of either river. But on the Ganges side, at the point B would be a deadly marsh, and the wide plain from B to C a dreary solitude. On the Jumna side, immediately above B would lie the factory of the Annfield Tea Company, and from B to C would be the land worked by the laborers of the native Christian village.

Colonel Cautley addressed a most interesting letter to the Military Board on the subject of the drainage of the Eastern Dhoon, dated 23rd April, 1842, to which I am indebted for many thoughts embodied above, and from which I take the following section and the accompanying sketch map.

It will be seen from the above section that the marshes are immediately at the foot of the high banks, or are in greatest force there. Colonel Cautley traces in this an analogy to the position of the silt deposits on the sides in the Doab canals. The active causes for this position of the marshes are, however, evident. The river has at one time flowed over these steppes, and the high bank has formed one of its banks, as is plainly proved by the boulders and shingle which still show them. It has left a hollow at the foot of these banks, and from these banks gush forth numerous springs, the drainage of the very absorbent high land above. The consequence is that in the wet hollow at the foot of these banks, ratans, reeds, and coarse grasses grow up, they spread out over the edges and prevent the water from passing off even from there. Large trees grow up with a luxuriant growth from the damp moist soil, and rank creepers twine round them. The water is held back more and more, and the evil goes

on increasing The mouths of the drainage lines cutting through the bank are blocked up, and add their waters to the swamp, which has now spread far and wide

The same causes may be seen at work in other parts of the Dhoon, as below the last steppe towards the Jumna, but producing the same effects, only to a limited extent, owing to the presence of artificial cuts and drains, and by artificial means it is possible to drain any marsh in the Dhoon, the slope of the land being so great, and there being so many large drainage lines traversing it Not many years ago a large marsh existed close to the village of Synspore, in the Western Dhoon "This marsh was well known to all tiger and deer shooters," says Colonel Cautley, "and there are now gentlemen living in the Dhoon, who have had their spaniels snapped up by alligators in it" It was "the blight upon health and happiness to all the villages in the country bordering it Its site, with the exception of a very trifling area, is now covered with wheat and rice crops" The village of Dakhee, to which these lands belong, was sold by a gentleman, when the marsh existed, for Rs 600 Its annual income is now more than that, and all this improvement was caused accidentally by the Zemindars digging a boundary ditch!

From the forest of the Rambuha Nuddee the approach to the Ganges is gained by two distinct steppes, the high land between the first and second steppe varying in width from two to two and a half miles On this elevated piece of land is situated the Goosemwalla marsh, containing three square miles or thereabouts of deadly swamp There are also other smaller ones, with numerous little twisted nullahs running sluggishly, with their courses marked by the densest vegetation and the most impracticable ratan jungle Below the second steppe is the true Khadir of the Ganges A portion of it is elevated sufficiently to allow of its being drained The Goosemwalla marsh approaches within half a mile the steppe into the Khadir Both it and the lower marsh are traversed by the Rambuha river It will appear evident on inspection of the sketch of the ground which accompanies this letter that there is every facility for effecting the complete drainage of this swamp (Col Cautley's letter)

He then goes on to describe the mode of operations he would propose "Without using any instruments and examining the ground methodically, it would be difficult to form an estimate of the expense that would be incurred in draining the Jogowalla and Goosemwalla marshes The work

IRRIGATION AND DRAINAGE

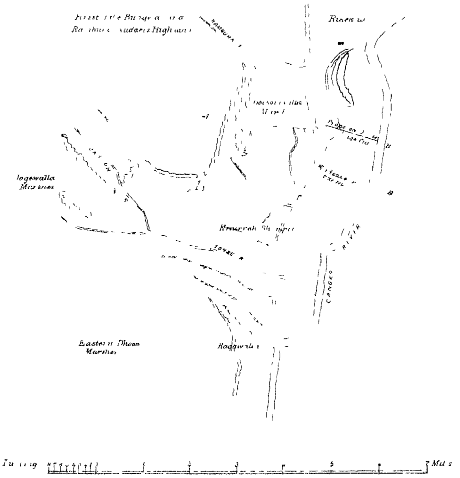
IN THE

DEYRAH DHOON

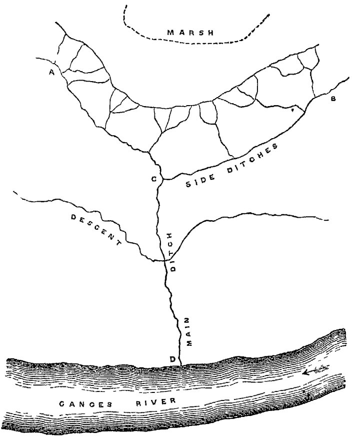
Sketch of the ... Deyrah Dhoon (East slope)

... the position

of the Jogewalla ... Marshes



could only be done by degrees I would commence operations on the Gooseinwalla marsh, the elevated position of which appears to be so peculiarly favorable During the first season a main channel dug back from



the low land into the marsh as far as workpeople could advance, might probably, in the course of the next year, reduce the extent of swamp Were this the case, branch and smaller drains might be dug ramifying into the heart of the marsh, by their means the spring heads might be gradually reached If all this succeeded, the gigantic reeds and grass, which now

render these places inaccessible, would give way to the smaller jungle, and the final operation would consist in clearing out the drains and keeping them well open."

I would change the order of operations as laid down above. The great object is to get rid of the water from as large a surface as possible in the shortest time. This the single deep pitch proposed to be dug first would not do.* I would not only ramify into the heart of the marsh by means of small drains, but I would approach its outer edge by their means. The plan of operation I would propose is similar to that employed in draining fen-lands in England.

CD being the main ditch, CA and CB should be smaller ditches running round the edge of the marsh, and from them should proceed the small drains, which need not be more than a foot deep which are intended actually to tap the marsh. This ought soon to produce a dry border, as shown by the dotted line. The canes, reeds and other aquatic plants would die and small grass take their place. The main ditch might then be pushed forward with a repetition of the same operations. All these smaller ditches and drains need not be dug more than a foot deep, so as afterwards to be easily ploughed over, only the main ditch and one or two lateral ditches would afterwards be allowed to remain.†

I have no doubt that the above mode of proceeding would be completely successful. It must, however, be necessarily slow in its operations, and there is therefore the more need that it should be taken in hand at once.

R. E. F.

* Not at first, but it would enable you to see your way and to determine what to do next, which can only be done by the officer on the spot.

† The general plan of operations here laid down may be adopted, though details can only be worked out on the spot, and as events turn out. There can be no doubt whatever that these fearful swamps, which now render this part of the Dhoon so deadly, be removed as speedily as possible, and that a comparatively small amount of money will, if laid out judiciously, enable this desirable object to be accomplished. Three years ago, and the Sooltanpore swamp in the Seharunpore district was as deadly and dismal as either the Goosein or Jogewalla swamps in the Dhoon are now, a few cuts made here and there at small expense have converted the whole area, formerly inhabited by wild animals, and covered with the long reed jungle, into one waving cornfield, and the like results would follow a similar small expenditure on these great and deadly marshes. Many years ago, Captain (now Colonel) Sir Proby Cautley, recommended "that Rs 1000 or Rs 1500 should be authorized for a period of five years for digging escape drains, and using other means if necessary, for getting rid of these nuisances."

Had this recommendation been sanctioned, it is hardly possible to say what would not be the state of this portion of the Dhoon at this present moment. I can only now reiterate the recommendation that Rs 1500 annually be granted for the purpose of making cuts into both these swamps, and that as at the best their drainage will take considerable time to accomplish thoroughly, as the matter is now under the notice of Government, that it be not put aside again for another ten years, but that the sum of Rs 1500 be allotted for this work for the next five years, and that the first allotment be granted from the Irrigation Reserve of the Budget of 1863-64, when a commencement of this work will be made during the next cold weather.

NOTES

First —I have been able to lay my hand again on my Notes on the Rajpootanah Tanks The following information is from them —

1ST —THE DURATHOO TANK

Contains 5,150 × 2,200 × 18 × ½ = 10,19,70,000 cubic feet, irrigates 280 acres, 3,64,000 cubic feet required for irrigation of one acre

2ND —KALLL KUNKUR TANK

Contains 5,015 × 1,470 × 28 × ½ = 10,32,08,700 cubic feet, irrigates 438 acres, 2,35,600 cubic feet required for irrigation of one acre

3RD —GOHANNA TANK

Contains 1,515 × 3,310 × 24 × ½ = 6,01,75,800 cubic feet, irrigates 280 acres, 2,40,700 cubic feet required for irrigation of one acre

And as shown before—

IN MADRAS

1ST —CHUMBRUMBAUKUM TANK

Contains 3,000,000,000 cubic feet, irrigates 10,000 acres, required for irrigation of one acre, 3,00,000 cubic feet

2ND —CAUVERY PAUK TANK

Irrigates 7,700 acres, required for irrigation of one acre, 2,86,000 cubic feet

From the above it is evident that at least 2,40,000 cubic feet of water are required for the irrigation of one acre in tank irrigation

Now, in my calculation—

SUPPOSED TANK

Contains 800 × 1 600 × 12 × ½ = 76,80,000 cubic feet, irrigates 100 acres *Allowed* for irrigation of one acre, 76,800 cubic feet

Taking it at 80,000 cubic feet, this makes my calculation out by a third *in favor of tanks*

My supposed tank was to cost Rs 2,500, and would produce Rs 50

Applying the correction of one-third, we should have Rs 2,500, bring ing in only Rs 16, which would be about *half* per cent

Tanks in the Dhoon would hardly therefore pay

Second.—The above difference in my calculation is caused in grea part by my having under-rated the loss by evaporation I took it o Colonel Cotton's authority at *one-quarter* inch per diem The following however, is the result of actual experiment —

DAILY RATE OF EVAPORATION IN CALCUTTA

October,	0 61 inch
November,	0 57 ,,
December,	0 47 ,,

Or about *half* an inch per diem

R E F

From Secretary to Government, N W Provinces, P W Departmen to Superintendent General of Irrigation

Dated Nynee Tal, the 26th May, 1863

SIR,—With reference to your Memorandum, dated 9th ultimo, givin cover to a report by Mr R E Forrest, late Superintendent of th Dhoon Canals relative to the improvement of the Dhoon valley, I an directed by His Honor the Lieutenant-Governor to observe, that th report is divisible into two distinct parts, 1st, Relative to the best moc of improving the means of Irrigation in the Dhoon generally, but chief in the Western Dhoon, 2nd, On the Drainage of the Eastern Dhoo The first fact, after disposing conclusively of the plan for storing r water in tanks or artificial reservoirs, brought forward by the commi sioner of Meerut, offers many suggestions which seem to be worthy further investigation

In regard to these I am to request that you will be good enough keep them in view, and to direct the present Superintendent of Dhoc Canals to carry them out by submitting projects in detail for them, fro time to time, as opportunities offer Funds will be assigned to the e tent that the budget provision for the Irrigation Department will admi

The Drainage of the Eastern Dhoon, I am to remark, is a most impor ant question, which it is greatly to be regretted has never yet be

seriously taken up Similar work on the great swamps near Saharunpore has been executed lately with perfect success, and there can be no doubt that even greater facilities, and a more certain prospect of effecting the object desired, exist in the Dhoon swamps Under these circumstances, His Honor authorizes you to spend annually Rs 1,500 from the reserve of the Irrigation Department in the drainage of these marshes

I am to add that, as estimates are quite out of the question, it will suffice if an annual report, showing progress made, is submitted at the close of each year's operations.

Although Tanks in the Dhoon might not pay as a direct speculation, *i e*, the water-rent realized would not return a fair percentage upon the first cost, it is difficult to believe they would not repay the cultivator by the enhanced value of his land, and Government by the enhanced revenue derived therefrom In a country of such very irregular surface as the Dhoon, it is probable that there are many natural hollows which require but a short length of embankment to convert them into extensive reservoirs, and supposing such to exist (which careful survey alone can determine) the other conditions necessary for a remunerative Tank are certainly present—that is, the extent of culturable land demanding water is large, the rain-fall during the season abundant, and the slope of the country more than sufficient It is much to be desired that the experiment should be made —[ED]

No VI

DESTRUCTION OF FORT SEORA.

From CAPTAIN J BAILLIE, *Executive Engineer, Jhansie Division, to* CAPTAIN J E T NICOLLS, *Superintending Engineer, 2nd Circle, N W Provinces, Allahabad*

Dated Jhansie, 23rd June, 1862

SIR,—I have the honor to report that agreeably to the instructions contained in Secretary to Government N W Provinces, P W Department letter, of the 23rd April, 1862, giving cover to correspondence on the subject of the Fort of Seora, in the Dutteah State, I placed myself in communication with Dr Stratton, Assistant Agent to the Governor General for Central India, in view to carrying out the proposed demolition, and was by him referred to Captain Thompson in charge of the Dutteah State

Captain Thompson proposed to accompany me at once to Seora, and I accordingly left Jhansie on the night of the 17th ultimo, and arrived at Seora on the morning of the 20th I proceeded immediately to examine the defences of the Fort, these have been already fully described in Captain Hovenden's report, and it is unnecessary here to repeat the description At first sight the most feasible method of rendering the Fort untenable appeared to be to destroy the various gateways on the east side, where the ground outside is much intersected by ravines, which would afford cover to an assaulting column close up to the walls This could have been done by simply exploding large charges of powder under the different archways and their points of support and abutments so as to shake them down, without the trouble of sinking shafts or proceeding to regular mining operations. But in consultation with Captain

Thompson, he appeared to consider that the instructions were to render the place untenable in a Military point of view, and that the destruction of the main gateway would impede the access to the Fort for ordinary purposes to an extent that would render it uninhabitable, which was not desirable, nor under the peculiar circumstances, perhaps justifiable. Under this view I decided to breach the south side by mining, as proposed by Colonel Tombs. I could not hit the precise line of Captain Hovenden's section, but I selected a point where the upper main wall projected some feet in advance for a length of about 75 feet, which appeared to give a facility of going deeper down before meeting the rock, and where a large mass of superincumbent masonry would furnish additional material for filling the deep ditch in front.

I commenced sinking four shafts, 25 feet apart, in rear of each revetment. These were intended to be carried down to two-thirds of the height, with Lines of Least Resistance, varying from one-fourth to one-sixth, but in consequence of the extreme hardness of the rock it was found necessary to modify these conditions slightly in one or two cases. The shafts were $3\frac{1}{2}$ feet in diameter, being the smallest space in which the men could conveniently work.

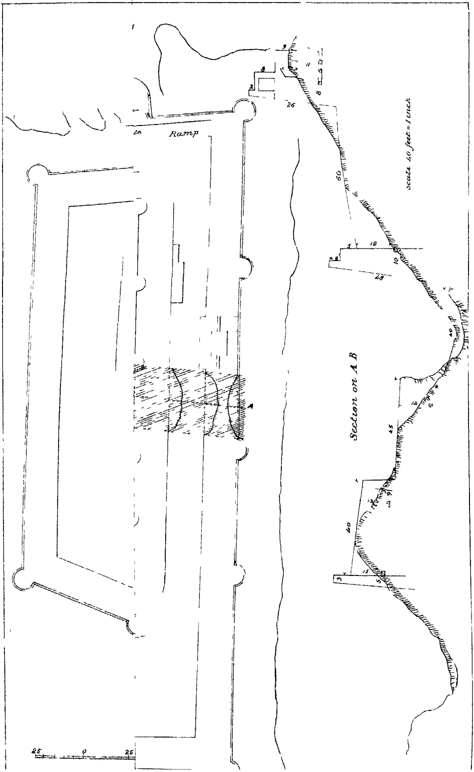
In calculating the charges, I estimated that taking into consideration the fact of the powder being entirely of native manufacture, and the masonry of great age and strength, that $\frac{LLR^3}{\text{[illegible]}}$ would not be too great, but on examining the powder I found that the greater part of it had been stored in a small building for at least 16 years, with no other protection from the weather than the mere building up the entrance with kucha masonry, and much of this powder was said to have been made at least 30 years before, and was caked into a hard mass, while the "koopas," in which it was stored were so injured by damp as to fall to pieces in lifting them. However, after carefully separating the damaged portion as far as practicable, and trying a few petty explosions with the remainder, I decided on using it, and increasing the charges by one-fifth or one-fourth as the nature of the masonry or rock to be removed, might appear to demand.

In charging the mines I was fortunately able to obtain the assistance of some fire-work makers from Inderghur, whom I entertained, in the hopes that from their being in the habit of handling powder constantly they would be somewhat more careful than the coolies employed in

moving it, one of whom commenced filling a basket with a *phowra* In the absence of sand bags the tamping was commenced with large clods of slightly moistened earth, the hose being protected by slips of plank As soon as the powder was secured, loose earth was thrown in to a depth of 3 feet, then a layer of clods well rammed, and another 3 feet of earth, and a fresh layer of clods to the extent of 2 LLR, after which the shaft was filled in with loose earth

Twelve shafts in the outer line of defences were ready on the 27th, and I commenced loading them, but only seven were completed that evening, in consequence of a dust-storm and a slight shower of rain, which interrupted the work As I had some doubts of the efficiency of the tamping, I determined to explode four of these mines at once before completing the rest, and arrangements were accordingly made for it on the morning of the 28th A quantity of hose had been prepared with the damaged powder sewn up in a cloth tube 1 inch in diameter, and the hose from the four charges being brought to a focus of equal radii, about 60 yards more was laid to a near bastion and a piece of portfire (native) fixed to ignite it As none of my workpeople had ever seen an explosion, I was obliged to fire the first myself Its success was most complete A few stones where thrown out horizontally from the revetment, when the whole mass of the wall for about 90 feet in length sank down as if gradually dissolving at the bottom No stones were thrown upward, and but little dust, and the tamping at the surface was scarcely disturbed The breach was perfectly practicable with a slope of about 50°

This being so far satisfactory, the other mines were quickly completed with the exception of those in the upper main *enceinte* of the place Here two shafts had been sunk in the building marked (*a*), from which I had intended to run short galleries right and left in rear of the revetment wall, but it was found to have been filled up with immense masses of rock, apparently taken out of the ditch in front, and it was found impracticable to get these out of the shaft or to work round them I accordingly sunk a fresh shaft a short distance in rear, where the ground appeared to be more favorable, and on getting down to 10 feet I ordered a gallery to be run forward 10 feet more, in order to place a large charge between, and rather in rear of the other two I expected that by firing the two front charges slightly in advance of the others in point of


Ramp
Section on A B
scale 40 feet = 1 inch
A
25 0 25

time that they would tear out the foot of the wall, and that the third explosion following immediately would throw the mass of masonry well forward into the ditch, as it turned out, however, this arrangement miscarried

The mines were fired in three groups, the first included the eight mines of the upper and lower counterscarps of the ditch As I was unable to fire them myself from illness, I arranged the portfire so as to protrude from the end of a small covered channel of some yards in length, so as to protect the hose from any possibility of ignition until the portfire (which was timed) had burnt through the lump of moist earth in which it was imbedded, thus obviating the risk of accident which so frequently occurs from the premature ignition of the hose The explosion was very effective, the lower mines exploded first, tearing out large masses of the red sand-stone, and throwing it with all the force of a salvo from a breaching battery against the opposite scarp, one stone being sent through the parapet The upper mines followed almost instantaneously, and were no less successful, leaving the ditch half filled with the *debris* Here again the tamping answered perfectly, and very little earth was thrown upwards, though the dust was almost suffocating for a few minutes

We then moved to the inner defences, and as soon as the hose had been arranged as before, the explosion took place The lower *(fausse braie)* mines were again fired first and were successful, but the upper ones in the main *enceinte* failed to bring down the wall, though the bottom was so torn and cracked that it appeared as if a few stones thrown on it must have sufficed to have done so

On examination, I found that the large mine in rear had exploded with great force, bringing down all the inner part of the building *(a)* but leaving the outer face almost untouched, from the large crater left by it, it was evident that the gallery had not been carried forward sufficiently, and that its Line of Least Resistance had been really vertical instead of horizontal On inquiry, this proved to be the case, the beldars who were employed in it finding the rock too difficult, had carried it no further than 6 feet forward, reporting it complete, and I had been unable to examine it myself before it was charged The vertical Line of Least Resistance was consequently only about 11 feet, and the horizontal line which should have been the least was nearly 18, thus throwing the whole force

of the explosion into the air, fortunately without damage to any of the neighbouring buildings, except the one which it was intended to destroy

The wall might easily have been brought down by half a dozen beldars working with the pick in a few hours, but independent of the risk of their burying themselves under it, the failure of the explosion (in the main wall of the fort) had evidently created a feeling of exultation among the natives, of which I was not at all disposed to permit them a long indulgence, and I decided at once on completing the work with powder We set to work at once, and in a couple of hours the ruins were sufficiently cleared away to allow me to sink two fresh shafts close to the former outer ones The wall was so much shaken as to render the excavation a work of no slight danger, and the beldars frequently left their work in a panic, but fortunately no accident occurred, and the shafts were ready by 3 o'clock, they were quickly loaded and tamped, and at 5 o'clock were ready for explosion A large crowd had assembled, with the secret hope that the wall would again resist the explosion, but they were doomed to be disappointed this time The mines were most effective, the huge mass of masonry first slid down a few feet then toppled over with a tremendous crash, and glided down through the breach in the *fausse braie* to the very bottom of the ditch, leaving a practicable breach from top to bottom with a continuous slope of nearly 80 feet high To satisfy both myself and the townspeople of its complete practicability, I offered a reward of a rupee to the first person who should reach the summit of the breach from the outside of the fort, and it was claimed in a few minutes by a boy from the crowd, who had already assembled there The work was now completed Captain Thompson expressed his perfect satisfaction with it, and nothing remained but to dismiss the working parties and collect and pack the tools brought with us, this was speedily done, and we left Seora the same night Taking into consideration my own utter inexperience of mining operations, and the entire absence of skilled labor or any European superintendence, I have reason to be greatful that the work has been successfully carried out without the slightest accident or injury to any person

The expense has been moderate, not exceeding Rupees 270, a large proportion of which was for carriage

I append a Tabular Statement of the details, &c, of the Mines, and Plan and Section of the Fort on an enlarged scale

TABULAR STATEMENT OF DETAILS OF MINES EMPLOYED IN THE DESTRUCTION OF FORT SEORA

Position of the mines	Number of shafts	Distance apart	Depth—feet	One or more lined crater	L L Running feet	Nature of the Revetment.	Nature of the soil	Charge $\frac{LLR^3}{3}$	Extra charge $+\frac{1}{4}$ to $\frac{1}{5}$	Total charge lbs.	Grand Total	Description of tamping	Remarks
Exterior Line (Scarp Revetment),	4	25	15	Single lined	5	Stone and lime masonry Stones small average 3½ c f each	Soil soft but mixed with kunkur and fragments of the rock excavated from the ditch.	42	(⅕) 8	50	200	Earth brought in from the river slightly moisten ed in layers then loose earth and stones alternately to the top of the shaft	The shafts were 25 feet apart The mines exploded simultaneously with excellent effect Breach 90 feet wide clear, slope 50°
Interior Revetment of Rampart of do , ..	4	25	12	do	9	do	do.	243	(⅕) 48	290	1 160	do	These two groups of mines were fired from a common focus the hose being led up the upper revetment The upper mines were slightly overcharged $\frac{LLR^3}{5}$ would have been sufficient
Main Ditch Counterscarp,	4	25	14	do	12	Unrevetted	Sand-stone rock.	576	(¼) 144	720	2,880	Do	
Fausse Braye Scarp	4	25	18	do	10	Stone and lime masonry very strong stones averaging 25 cubic feet	do	334	(¼) 88	422	1 688	do	These mines with the three above were exploded together the lower ones slightly in advance of the upper The effect of these was good the explosion bringing down part of a small tower on the left of the upper mines, the outer ones were partially successful tearing out large holes in the foot of the wall but the inner one failed for the reasons detailed in the report the charge being placed too far back
Enceinte Curtain	2	75	11	do	8	do do The revetment filled in behind with large stones	do	171	(¼) 43	214	428	do	
Do do ,	1	Between the other two	11	do	12	do do	do	576	(¼) 144	720	720	do	
Do do ,	2	30	10		8	d do	Ditto was much shaken by the previous explosions.	171	(⅕) 34	200	400	do	Very successful bringing down the whole mass of masonry
											7 476		

JHANSIE,
23rd June, 1862

W BAILLIE, CAPTAIN,
Executive Engineer,
Jhansie Division.

No VII

TEMPORARY ROAD OVER THE SANDY BED OF THE CHENAB

Description of a Temporary Road across the Sandy Bed of the Chenab River By E B MEDLEY, ESQUIRE, *Assistant Engineer, Lahore and Peshawur Road*

THE total length for the roadway across the Chenab measures 10,600 running feet, of which 1,350 feet consists of a metalled road laid down last year, and now in good order, 3,500 feet resting on firm soil, extending from the road embankment to within 1,000 feet of south side of river, and the remaining 5,800 running feet extend across entire sand

In the last mentioned length the hollows and low points across the sand are not very numerous, so a depth of 9 inches will provide for the various excavations and fillings in, so as to form a bed for the finished road to rest upon

The distance to carry the earth is a mean of about three-fourths of a mile In consequence of the difficulty of procuring laborers at this season of the year, 1 rupee per 100 cubic feet has been calculated per mile, and an additional rupees 2-8 per 1,000 cubic feet for digging and loading

With regard to the cost of the fascine portion of the road, the following experiments were made —4 coolies were set to work to cut grass under close supervision, working 7 hours during the day, the area thus cut measured about 15,000 superficial feet, and the quantity of grass realized weighed nearly 23 maunds

From this quantity of grass, 29 fascines, 6 inches in thickness, and 24 feet long, were obtained

The labor for making up the above, consisted of 6 men working seven hours of the day

For the loose grass required as a top-covering, the total area required is 5,800 × 24 = 1,39,200 superficial feet On the same quantity of grassing being spread out one-half inch thick, and strewed over the surface sufficiently to cover the ground, the area thus covered measured 160 × 24 or 3,840 superficial feet

The labor in spreading the above consisted of 2 men working under supervision for 6 or 7 hours of the day, the grass being neatly packed

The distance for carrying the fascines and loose grass for road surface, is about the same as that for earthwork

---

Specification —The roadway to consist of one layer of grass fascines, each fascine to be 24 feet long, 6 inches in diameter, and tightly bound with grass, to be packed closely together and covered with 6 inches of clay On the surface of the clay and to prevent its cutting into grooves, a very thin layer of loose grass will be constantly maintained An inch of clay will be first laid down on the sand, all hollows to be filled in and low points to be somewhat raised, that the foundation may not suffer from the lodgment of water

In other places the finished road to be 1 or 2 inches above the sand

---

ABSTRACT OF COST

			R	A	P
r ft.					
58,000	Road fascines, at Rs 2-8 6 per 1,500,		978	12	0
s ft					
1,39,200	Loose grass, at Rs 1-14-6 per 3,840,		69	1	7
c ft					
3,04,400	Sand, at Rs 1-12 0 per 1,000,		182	11	2
58,000	Earth, at Rs 10-0 0 per 1,000,		580	0	0
		Total,	1,810	8	9
	Contingences at 5 per cent,		90	8	5
		Total,	1,901	1	2

Being Rs 1-4 per 100 superficial feet, or Rs 33 per 100 lineal feet of roadway The work was executed under the above sum and has answered well, effecting a considerable saving in the tractive force required through the heavy sand Though such a road will only last one season, its utility and economy will always justify such a construction being employed in all lines of heavy traffic Wherever the fascines can be pegged down the improvement will be great —[ED]

No VIII

TRIGONOMETRICAL SURVEY OF TASMANIA.

Notes on the Trigonometrical Survey of Tasmania BY COLONEL H C COTTON, *Chief Engineer, Madras Irrigation and Canal Co*

A TRIGONOMETRICAL Survey of the Island of Tasmania, on principles, and with means ensuring the greatest accuracy, was effected under the Government of Sir W T Denison, K C B, in the years 1849-50 and 1851 Its progress and results were made public by insertion in the Journal of the Royal Society of Tasmania, but as they appear to have excited no interest out of the colony, it is considered desirable to lay the description of the survey anew before the Public

The Survey is remarkable for extreme accuracy, equalling, if it does not surpass the best on record in Europe, India, and America, and it is believed that the comparison of its results with those of other surveys, will be neither uninteresting nor unprofitable

The Survey was commenced before suitable instruments were procured from England, but it will be as well to give the history of the operations from their commencement

The first work was to prepare rods for the measurement of Base Lines A well seasoned spar of Baltic fir was procured from the shipping in the harbour of Hobart Town, and cut into rods about 15 feet in length and 2 inches square They were nicely planed, saturated with boiling oil, and varnished, then rolled in flannel, and packed in dry saw-dust, in coffers, 6 inches square The coffers were closed at the ends, but leaving space for the rods to expand or contract freely, and the rods were supported centrically in them, by blocks of wood fitted carefully, but not fastened Lastly, the coffers were covered with a good coat of paint

To the ends of the rods were attached brass caps, rising to the level of the outer surface of the coffers, and on these were engraved the scales by which the lengths of the rods were determined, and their distance asunder, when laid. One cap bore a zero mark only, and the other a vernier scale 19-20th of an inch, divided into 20 parts, to accord with the divisions of a 4-foot steel standard, the only reliable standard then in the colony.

The rods, as will be shown, worked with remarkable precision, but the scale being inconvenient, and incurring much unnecessary work in the calculations, was exchanged for a decimal scale, as soon as a good dividing apparatus could be procured from England, but the first measurement of the base at Ralph's Bay was in the mean time proceeded.

One end of this base was at the sea level, while the other end rose with

some feet higher. Both were well situated as trigonometrical stations.

The Base was about 4 miles in length. It was divided into gradients or hypothenuses, to suit the undulations of the ground, and their inclination to the horizon was ascertained by levelling. The rods were placed on tressels, fitted with screw lifts, by means of which, they were laid in their true position in the vertical plane. Their correct alignment horizontally, was effected by hand, under the guidance of a transit instrument. The first rod was laid within a few inches of a permanent mark established as a terminus of the base and a future trigonometrical station, and two others in succession,—their ends not in contact—but at similar intervals, the zero mark on one rod being antagonist to the vernier scale of the next. The rods were then carefully measured by the 4-foot standard, and their lengths recorded, as in Table A, with the temperature of the standard at the time. The intervals were then measured by a small scale engraved for the purpose, its divisions being copied from the steel standard.

The manner of recording these measurements is shown in Table B.

Three rods only were used, two always remaining in position while the first was removed and placed in advance. Table B show the manner also of summing up the length of each hypothenuse, and reducing it to its horizontal value.

The lengths of the rods were checked by frequent measurement during the operation, but were not found to vary appreciably.

Thus far the imperfect means at hand in the colony had been alone used, and in this it had been necessary to make a dividing and copying machine, and to engrave by its means the scales described above. It was, however, done with very fair success, as will be seen in comparing this first measurement with the subsequent measurements of the same base.

In 1851, the instruments for the Survey arrived, which had been commissioned from England by Sir William Denison, and were selected by Mr. Airy, Astronomer Royal, and Capt. Yolland, R.E., Director of the Trigonometrical Survey of England.

The instrument for angular observations was a 12-inch altitude and azimuth instrument, the graduations of which read to 10 seconds, with a cast-iron repeating table of excellent finish and very portable. With this was received a 10-foot steel standard bar, (one of those employed in the measurement of the Lough Foyle base,) and a good dividing apparatus.

By means of the latter instrument new scales were divided, and decimal divisions were adopted, true to the 5,000th part of a foot, by which means the calculations were much simplified.

The second measurement of the Ralph's Bay base was then made, using the same rods, but with some trifling additional caution in laying them, and their lengths and the intervals were measured by the new scales, and referred to the new standard. On the completion of this, the third measurement was immediately made, and in the same manner.

The Base of verification at Longford was then marked out, and measured twice in the same way and by the same means. It was situated about 90 miles from Ralph's Bay, and 50 miles from the north coast of the island. It was nearly 5 miles in length, and about 40 feet above the level of the sea. The two extremities were good trigonometrical stations. 4 miles of the base were on a nearly level plain, and 1 mile considerably inclined. Here again the testing of the length of the rods indicated no variations, and no reduction was on that account necessary.

The following Tables are merely extracts from the field-books, and show both the measurements recorded, and the mode of making the reductions. The three rods were marked A, B, and C, for distinction.

TABLE A

Measurement of the Rods

Thermometer	Rods twice measured, 29th April	Mean of two measurements, reduced for temperature	Remarks
	Feet	Feet	
Deg 60	A { 15 1150, 15 1150 }	15 1148	The reduction for temperature of standard is 000007 foot for each degree above or below 62 degrees per foot of length
61	B { 15 1316, 15 1316 }	15 1315	
61	C { 15 10475, 15 1048 }	15 1047	

The reductions were not made in the field, but the rods under their several designations were entered with the measurements of the intervals in the field-book, as follows —

TABLE B

Measurement of Base

No of hypothenuse and date	Rise and fall	Measured intervals and rods	Reduced horizontal measurement
	Feet	Feet	Feet
No 61 29th April	Fall, 2 187	1588 A 3328 B 3456 C 3790 A 3390 B &c, &c, &c	
		Part of C = 5 0042	
15 1148 × 4 =		4 A = 60 4592	
15 1315 × 4 =		4 B = 60 5260	
15 1047 × 3 =		3 C = 45 3141	
Total hypothenuse,		175 3137	
Deduction,		013642	175 300058

NOTE.—AB = Measured Hyp $\overline{2\,AB - Bd} \times Bd = BD^2$

BD = Observed fall

$Ad = AD = AB - Bd =$

horizontal value

When the rise or fall does not exceed $\frac{1}{50}$ $Bd = \frac{BD^2}{2AB}$ is correct to the *seventh* decimal, and gives the required deduction, and when the rise or fall is greater, this may be used as an approximation, in the second operation $Bd = \frac{BD^2}{2AB - Bd\,(Ap)}$ thus—

$$\frac{(2\ 187)^2}{175\ 3157 \times 2} = 0136 \text{ approximate deduction}$$

$$\frac{(2\ 187)^2}{(175\ 3137 \times 2) - 0136} = 013642 \text{ true deduction}$$

The several hypothenuses, thus reduced to their horizontal value, were then classed for reduction to the level of the lowest point, for the purpose of reducing the labor of calculation Each class consisted of those not differing more than 50 feet in elevation above the lowest point, and a multiplier for each class being computed as under, the reductions were effected with the least possible amount of calculation

r = Earth's radius + elevation of lowest point above the sea

a = Elevation of each class above lowest point

b = Sum of each class reduced to horizontal

c = Each class reduced to its value at the lowest point

$c = \frac{r}{r + a} \times b$ giving $\frac{r}{r + a}$ for the multiplier to be calculated for each class, applied as under

For those hypothenuses which are under 25 feet above the lowest point, no reduction is required, the multiplier in that case becoming nearly unity

TABLE C

Reduction to the Level of Lowest Point

Hypothenuses classed	No of Class.	Sum of reduced Hypothenuse (Table B) in each class — Feet	Mean elevation of each class above lowest point — Feet	Calculated multiplier $\frac{r}{r+a}$	Each class reduced and total base at lowest point — Feet
Nos 12 to 20	1st	5399 917769	under 25 ft	No reduction	5399 91776900
Nos 1 to 11 and Nos 21 to 31	2nd	12501 603354	$a = 25$,,	99999880325	12501 58339270
Nos 32 to 50	3rd	5414 243631	$a = 50$,,	99999760650	5414 24233510
Nos 51 to 61	4th	2430 283744	$a = 100$,,	99999478430	2430 27094685
Total base reduced to lowest point—feet, ..					25746 019433

For the reduction to the level of the sea

h = Height of lowest point above the sea

r = Earth's radius

B = Base at level of lowest point

B^1 = Base reduced to the level of mean tide

$$B^1 = \frac{r}{r+h} B$$

The lowest point of the Ralph's Bay base being at the sea level, no reduction was required under this formula

The lowest point of the Longford base was 405 feet above the sea, and the reduction was as follows —

$$B^1 = \frac{r}{r+h} B = \frac{20887685}{20888090} \times 25746\ 2 = 25715\ 7 = \text{Longford base,}$$

finally reduced

The result of the three measurements of Ralph's Bay base was as follows —

1st	Measurement in 1849,-	- -	20182 484496 feet
2nd	1st ,, in 1851,-	- -	20181 692922 ,,
3rd	2nd ,, in ,, -	- - -	20181 577215 ,
	Means of 2nd and 3rd measurements,	-	20181 635068 ,

Difference from 1st, 849 feet = $10\frac{1}{5}$ inches

Difference of 2nd and 3rd = 115 feet = $1\frac{1}{3}$ inches

The comparison of these measurements showed satisfactorily that the mean of the two last might be adopted as the true length of this base, viz , 20181 635068 feet

The measurements of the Longford base resulted as follows —

1st Measurement, - - - -	25746 019443
2nd ,, - - - -	25746 304833
Difference, - - -	285390 feet, or

$3\frac{1}{2}$ inches nearly

This difference of $3\frac{1}{2}$ inches in a base of nearly 5 miles, is almost as close an accordance as $1\frac{1}{3}$ inch in the two last measurements of the Ralph's Bay base of 4 miles, and indicating, it is believed, unequalled accuracy, but the great test has yet to be shown, in the result of the triangulation from base to base verified by these measurements

The main trigonometrical stations were for the most part on Mountain Peaks, and the Capes and Islands on the Coast

The highest were bare basaltic or greenstone peaks, those of intermediate elevation required to be cleared of very heavy timber

The Stations were all circular stone towers except where a single tree could be left The observations except in very few cases, were taken from the centres of the stations

The Triangles were of from 12 to 30 miles sides The first series from base to base 13 in number, were well conditioned, and at one angle only, the observations were taken out of the centre and reduced

The Instrument described above with its repeating table, was used for the angular observations, and in this first series and about 300 other calculated triangles, where the repeating table was used, the sum of the angles, allowing for spherical excess, never erred to a greater extent than four seconds, rarely above two seconds

The error was equally divided between the three angles, except where the field-book had noted any atmospheric disturbance which might have affected an observation, in which case the weight of the angle was duly considered in the division of the error

The first verification was obtained by a comparison of the measured length of the base at Longford, with its computed length carried from the Ralph's Bay base through the thirteen triangles above described, and the result is shown below

The same test was applied using other series of triangles more and more remote, as follows —

Mean of measured lengths of Longford base reduced to the level of the sea,	25745 7				
Length computed by 1st series	25746 0	difference +	3		
Do do 4th „	25746 2	„	+ 5		
Do do 2nd „	25744 5	„	— 1 3		
Do do 3rd „	25743 5	„	— 2 2		
Do do 1st series, varied in one triangle,	25745 35	„	— 35		

The first series, composed of the fewest and best conditioned triangles, gives the best result, the difference between the measured and computed length being $3\frac{1}{2}$ inches in nearly 5 miles

The fourth series shows a difference of 6 inches only, the second and third $14\frac{1}{2}$, and $26\frac{1}{2}$ inches, severally, and a variation in one triangle of the first series closely accords with the first in amount of difference, but minus instead of plus

It is in these strikingly close results that the Survey claims notice and and comparison with other surveys

With the exception of the South-West quarter of the Island, the observations were made throughout with the same instruments, and the same care, and testing the work by calculating a line by various series of triangles, the smallness of the differences proved the great accuracy of the whole Over the South-West portion, then very difficult of access, the repeating table was not carried, and the observations in consequence were less accurate, but even to the South-West Cape the work was sufficiently true, to ensure, by taking the mean length of sides calculating through various courses, a very perfect degree of accuracy It was computed that the Capes could not anywhere be out of position one-third of a second in Latitude and Longitude

At many principal stations, True Meridians were determined by elongations of circumpolar stars

The heights of the several Mountain Peaks, and Table Land in all parts of the Island, were ascertained by angles of elevation and depression, as well as by the Barometer These observations were made by the same instrument, and at the same time as the horizontal angles for the triangulation

The following extracts from the field-books and books of calculations, will exhibit the course adopted both in observation and computation, and the degree of minuteness aimed at and realized

TABLE D

EXTRACT from Field-book of 12-inch Altitude and Azimuth Instrument, as adopted by Mr Sprent, the Observer at the Main Stations

DROMEDARY STATION

Stations and stars observed to	No of repetitions	OBSERVATIONS			
		HORIZONTAL ANGLES			
		Reading Deg Min	Reading Three Verniers Seconds	Mean Reading Deg Min Sec	Angles Deg Min Sec
Butler's Hill,		47 57	75 65 25	47 57 55 0	
Platform Peak,	1	290 46	10 30 25	290 46 21 6	117 11 33 4
	7	307 36	40 40 45	307 36 41 6	117 11 34 2

Stations and stars observed to	No of repetitions	ELONGATIONS				
		Reading Deg Min	Reading three verniers Seconds	Mean Reading Deg Min Sec	Reading of Levels, each 2 Seconds	Date
Brown Mountn,		89 59	60 60 40	89 59 53 3	39 29	June 5th, '61
N Argus,		155 56	90 50 70	155 57 10 0	35 32	
Brown Mountn,		89 59	60 55 35	89 59 50		
α Crucis, E,		161 19	55 10 30	161 19 31 3	43 26	
Brown Mountn,		89 59	70 65 45	90 0 0 0	43 26	

Stations and stars observed to	No of repetitions	ELEVATIONS AND DEPRESSIONS						
		Barometer	Thermometer Att	Thermometer Detd	Reading Deg Min	Reading of Verniers Seconds	Mean of Verniers	Angle Deg Min Sec
Rumney's hill, top of stone,		27 016	46	46	88 46	74 40	57	1 13 8
					1 12	36 24	30	1 12 30
					88 46	74 42	58	1 13 2
					0 12	38 24	31	1 12 31
					88 46	74 44	59	1 13 1
					1 12	38 24	31	1 12 31
						Mean Angle,		1 12 45 6

TABLE E

Extract from Book of Triangles

Number of Triangle	Angular Points	Number of Repetitions	Spherical Excess Seconds	Observed Angle Deg Min Sec	Corrected Angle Seconds	Angle reduced for Spherical Excess * Deg Min Sec	Sine of Angles	Logarithm o opposite sides	Sides in feet
	Mount Argus,	28	3 1	55 37 41 2	41 5	55 37 40 5	9 9166585	5 1042901 †	127142 31
No 11	Miller's Bluff,	10		42 5 38 8	39 5	42 5 38 5	9 8263011	5 0139327	103260 14
	Dry's Bluff,	11		82 16 41 6	42 1	82 16 41 0	9 9960438	5 1836754	152642 46
				180 0 1 6	180° 0′ 3 1″	180 0 0 0			
				Spher ex. 3 1					
				Error — 1 5					

* The spherical excess is calculated by multiplying the area in square miles (from a simple plotting of the triangle) by 0132 One-third of the spherical excess is deducted for each corrected angle.

† Given side.

TABLE F

EXTRACT FROM BOOK OF CALCULATIONS OF LATITUDES AND BEARINGS

E —Observed greatest elongation of a star

EE—Angle subtended by point of reference and star at its greatest elongation, East.

WE—Angle subtended by point of reference and star at its greatest elongation, West

A—Elevation of star at its greatest elongation

PD—South Polar distance of star

L —Latitude of place of observation

DROMEDARY STATION

(Latitude by two elongations of α Argus)

	° ′ ″		° ′ ″
1st Obsn α Argus, East	179 29 16 6	α Argus, West,	247 10 3 3
Brown Mountain,	124 35 53 3	Brown Mountain,	80 15 16 6
Angle EE =	54 53 23 3	WE =	166 19 46 7
2nd Observation,	- -	α Argus, West,	181 24 25 0
		Brown Mountain,	15 14 35 8
		WE =	166 19 49 2
		Mean WE =	166 19 47 9
		EE =	54 53 23 3
			2)111 26 24 6
		E =	55 43 12 3

$\text{Cos L} = \dfrac{\text{Sin PD}}{\text{Sin E}}$

$\text{Sin A} = \dfrac{\text{Sin L}}{\text{Cos PD}}$

$\text{Sin E} = \dfrac{\text{Sin PD}}{\text{Cos L}}$

	° ′ ″		
α Argus PD =	37 23 1 8	-	Sin = 9 7832971
E =	55 43 12 3	-	Sin = 9 9171355
L =	42 42 38 8	-	Cos = 9 8661616

Assuming this to be the latitude of the Dromedary Station, A and E are calculated for other stars by the above expression

α Crucis PD = 27 43 32 2 Catalogue

	° ′ ″		
L =	42 42 38 8	Sin = 9 8314204	Cos = 9 8661616
PD =	27 43 32 2	Cos = 9 9470343	Sin = 9 6676750

Nat Sin A = 77 = 9 8843861 E = 39° 17′ 1 1″ Sin = 9 8015134.

TABLE F (*Continued*)

Bearing by elongation of α Crucis

Observation	{ Brown Mountain, / { α Crucis,	° ′ ″ / 89 39 55 0 / 161 19 31 3	Level 3	{ 43 26 / { 43 26
		——— / 71 19 36 3		——— / 43 − 26 = 17 + / 17 × 77 = 13 09 +
Correction for level,		+ 13 1		(17 × Nat Sin A)
		——— / 71 19 49 4 / E = 39 17 1 1		

Bearing of Brown Mountain, South 110 36 50 5, East

In like manner the bearing of Brown Mountain was ascertained from other observations at the Diomedary station, and the mean of all was taken with the following result —

	By East elongations ° ′ ″	By West elongations ° ′ ″
α Crucis,	110 36 50 4	
Do,	110 36 46 7	
β Argus,	110 36 54 0	
Do,	110 36 50 8	
Do,	110 36 54 0	
α Argus,	110 36 36 4	110 36 33 1
Do,	110 36 36 4	110 36 32 2
β Centauri,	110 36 11 9	
α Eridani,		110 36 58 6
	110 36 43 6	110 36 40 3

Mean of all, 100 36 42 4

Correct Bearing of Brown Mountain, South, 110 36 42 4, East

In like manner at Brown Mountain the Bearing of the Diomedary station from three Eastern and four Western elongations was found to be . South, 69 6 25 2 West

Convergence of meridians,	0 16 42 4
	69 23 7 6
	180 0 0 0
Bearing referred to meridian of Diomedary station, South,	110 36 52 4, E

Bearing from observation at Diomedary station, as above,	S 110 34 44 4 East
Difference,	10 0″

The convergence of the meridians was computed by the formula

$$Z - z = 180 - \frac{w}{a} \times d \text{ sine } z \text{ sec } L \text{ sin } \tfrac{1}{2} (L + l) \text{ sec } \tfrac{1}{2} (L - l)$$

where Z and z are the azimuths at the two extremities of the line from station to station—

L l—Their latitudes.

a—Earth's radius in feet

d—Distance or length of line in feet

w—206264 8 seconds in earth's radius

The convergence was also computed by comparing the length of a degree of parallel at the latitudes of the two stations, thus—

36549 2 cos lat $-$ 305 8 cos 3 lat $+$ 4 cos 5 lat $=$ length of one degree of parallel at the latitude of the station, (their difference giving the convergence in feet due to the difference of latitude) and

$$\frac{\text{Convergence in feet}}{\text{Difference lat in feet}} = \text{tan angle of convergence}$$

The above calculations of Azimuths and Latitudes depending entirely on local observations, they were checked with reference to the latitude of the Observatory at Hobart Town through the triangulation, the formula used being $L - l = \left(\frac{w}{a}\, d \cos z - \frac{wd^2}{8\,a} \sin^2 Z \tan l\right)$ seconds, for the difference of latitude of any two stations whose distance has been calculated and relative bearings determined When the operations were discontinued, these checks had not been fully carried out

The Secondary Triangulation had been commenced in the most occupied part of the island , and could have been carried on at a very small expense, but the whole was abruptly abandoned

A new map was elaborately constructed upon the unsatisfactory foundation of the Main Triangulation with the almost entirely unconnected, and generally incorrect, surveys of townships and land allotments, made separately and for special purposes For nautical purposes the map is true, as all the principal Capes were fixed by the triangulation, and all remarkable Mountain Peaks are main stations, and are true in position on the map The Survey, therefore, was by no means in vain, but it is much to be regretted that the secondary triangulation was not carried on through all the occupied part of the country, and the

Main Stations, in the still untrodden wilds, carefully and permanently preserved

The writer of these notes cannot lay them before the public without an apostrophe to the Queen Island of the Australian future empire

Tasmania, now lying prostrate and struggling for vitality—Tasmania with all its perfection of climate and soil, its still undeveloped mineral resources, its harbours, its rolling and flowing waters, and its forests of unequalled timber, with its fitness for the culture in perfection of all the cereals, fruits and flowers of Europe, and the introduction of all animals employed in the service of man—Tasmania might be—Tasmania will be—the garden, and the mine of Australia, the centre of its world wide commerce, the Koh-i-noor of its future crown Mighty changes are rolling rapidly over the nations of the earth, and the recovery and advancement of Tasmania may in the providence of God be near at hand Then the value of the Survey will be felt and acknowledged, and measures no doubt will be taken for its restoration The instruments are still in the island or at Sydney, the records (if not destroyed) are in the hands of the Government of Tasmania, and, if so, the Survey may be revived at some cost, without actual recommencement, and carried on to completion But in the mean time the same instruments could effect the same results elsewhere

New Zealand and the coasts, at least, of the great Australian continent (the latter connected across Bass's Straits with the Tasmania Survey) might be undertaken, and one great object in the publication of these notes is, to draw attention to the facility with which those important surveys can be effected.

H C Cotton

For the class of instruments used, the results of this Survey are singularly accurate The superiority of compensation bars, however, over deal rods is shown in the measurement of the Deyrah Dhoon Base of Verification in 1835, by Lieut -Col Everest, then Surveyor General of India, the difference between the two actual measurements being only 19972 feet in a length of nearly 8 miles

The difference between the mean Base so measured and its computed length brought up from the Seronj Base, a direct distance of more than 400 miles was only 0 6 feet

The Vizagapatam Base measured last year $6\frac{1}{2}$ miles long, differed only one inch in the two measurements; the error of the computed value as brought up from the Calcutta Base through a distance of nearly 5000 miles is only *one-quarter of an inch*

The average error of principal triangles observed during last year was 0·65 seconds, the Instruments used being 2 feet and 3 feet Theodolites

In the operations of the Indian G T Survey, the horizontal error in each triangle instead of being divided equally amongst all three angles, is divided according to the probabilities of error of the sets of observations from which each angle is derived A correction is also applied on account of the ellipsoidal form of the earth, besides the ordinary one for spherical excess —[ED]

SOME REMARKS ON THE LATE SANITARY COMMISSION

Serious as are the evils brought to light in the Report of the Commission appointed to enquire into the Sanitary state of the British army in India, it is consolatory to remember that much has been done of late years to remedy those evils, and that much of what is complained of belongs already to the past. The enquiries of the Commission extended back through the last fifty years, the laws of Sanitary science have scarcely been enunciated for fifteen, that is to say, since the outbreak of Cholera in England in 1848, a date contemporary with our occupation of the Punjab and the construction of a large number of new Stations and Barracks. Undoubtedly, in some cases, mistakes were made in choosing and erecting these, but much care was employed in the selection of the sites,* and the comfort and health of the soldier carefully studied in designing the plans. Sites were chosen by just such a Committee as is recommended in the Report of the Commission—the Civil, Military, Medical, and Engineering interests having been

* A remark may here be made as to the choice of Cantonment sites. The ugliest and most barren spots have as a rule been selected. This has no doubt partially risen from a disinclination to occupy cultivated land, but it seems also to have been due to a vague idea that trees and vegetation in general were unwholesome. Granting that rank vegetation, such as close underwood or dense jungle, shows generally that a site is unsuitable for building, yet on the other hand it may be taken as a safe general rule that the presence of healthy vegetation, such as trees, wheat crops, &c, as distinctly mark the healthiness of a place. From a neglect of this consideration it arises that having selected such a site as Mean Meer for instance, a barren plain absolutely devoid of vegetation, trees cannot be induced to grow, and the place seems as likely to be unfavorable to human as it is to vegetable life.

The intermittent fevers so prevalent in the Punjab, used at first to be invariably attributed by *medical men to the influence of 'stagnant water' or decayed vegetation,'* and the example of Peshawur was always adduced in proof. Yet in the year 1851, six hundred men of one regiment alone then at Mean Meer, were floored by this fever

always represented. Those who have seen the barracks at Sealkote, Mean Meer, or Rawul Pindee, with their wards 24 feet high in the clear, and their double verandahs, exclusive of which an allowance of 1000 cubic feet or 61 superficial feet, per man, has been made in point of space, will not consider that the soldiers are rendered unhealthy by over-crowding. Indeed the cost to Government for housing the troops at those stations was not less than 1,200 to 1,500 rupees per man, rather more than the cost to each officer of housing himself.

Bearing in mind this large expenditure, it is not at all clear that the best form of barrack has been hit upon so as to secure the maximum of comfort as well as health, to the occupants. Lofty and well ventilated as the Punjab barracks are, they are very cold and cheerless in the cold weather, while in May and June it is almost impossible to exclude the hot winds or cool the huge wards artificially. The half company barracks at Nowshera, in which each ward forms a separate room for twelve men are the most comfortable I have yet seen, and it is understood that the present Public Works Secretary in the Punjab, has proposed to carry out this plan still further by building a series of detached buildings to hold a few men each, in lieu of the present large barracks for a number. Although, at first sight, it would seem a more expensive plan, as demanding the same amount of roofing and flooring surface with a greater number of walls, yet on the other hand less lofty and substantial walls would be required for smaller buildings, so that the difference in cost would probably not be great. The advantages claimed are, that the soldiers would have a more home-like feeling about such buildings, and with the greater privacy secured, they would gain more self respect, while, under proper supervision there is no reason that discipline should suffer by the change.

It is often forgotten that we cannot locate our troops where we

Bahadoor Khail, on the Trans-Indus frontier, another barren spot, is continually scourged by the same disease. This form of fever as a rule seems most prevalent in places close under the hills, and Captain Dyas, R.E., suggested some years ago that stagnant *air* caused by the proximity of the hills, had probably more to do with it than stagnant water.

like in India, and that though no doubt it would be very desirable to have them all quartered in the healthiest places, yet the proper military occupation of the country is the first point to be considered, and thus the choice of a site for a cantonment is generally very narrow. Thus was Barrackpore originally fixed upon to watch the Danish Serampore, Berhampore to over-awe Moorshedabad, Dinapore to look after Patna, Cawnpore to watch Oudh, and so on. When the several lines of railways are completed throughout the country, much of this may be changed and our troops concentrated in healthy places, but even then people judging in England are apt to forget our immense distances, and in case of a popular insurrection, a railway is very easily disarranged.

What has been said above as to the proximity of large towns to cantonments, points at once to a chief cause of the unhealthiness of the latter, and to the remedy to be applied, both of which are pointed out in the Report. A densely crowded native city with narrow unpaved streets, and an utter absence of all drainage or sanitary arrangements, must be such a hot-bed of disease that we surely cannot have far to seek for the cause of cholera. Much has been done within the last few years, but much more remains to be done in this direction. Many of the larger native cities have been paved, partially drained, and conservancy arrangements initiated, but no one can go through the smaller towns and villages, where no European authority is present on the spot, without seeing how much reform is needed. As these improvements are carried out by local funds, it is no doubt easiest to raise the necessary funds in the great towns than in the small ones, but even these could in most cases be very much improved at a trifling expense, and every town or village not so improved is a public nuisance dangerous to others besides itself, and should be treated accordingly.

Drainage is not generally a difficult matter, most towns and villages, in the Upper Provinces at least, being built upon elevated spots. If old walls, ruined or half built houses (which become mere receptacles of filth) were pulled down, dung heaps removed, and no new houses allowed except on some uniform plan, much would

be done at a very trifling cost The paving and drainage of the streets is a more serious matter, but is after all not expensive, and the measure is imperative It is hopeless to expect to carry the uneducated people with us generally on these points, looking as they do upon disease as a fatality, and not as a preventible evil, but we had, and still have, the same difficulty in England, and the Hindoo is certainly more cleanly than the English laborer It is just one of those cases where the people should be coerced, not merely for their own good but for that of all around them

The best method of conservancy for towns or cantonments is still an open question In large cities, such as Calcutta, where there is money to pay for an elaborate system of covered drains and sewage, we have European experience to guide us But few native towns could afford to pay for such a scheme, even if there were always a natural receptacle at hand for the discharge of such sewage, while in cantonments it would obviously be impracticable The system of cess-pits is now strongly condemned, and the dry conservancy method, as it is generally termed, whereby night soil and refuse is carried bodily away and deposited in the earth, is pretty generally advocated Still this, though applicable to a cantonment, would not do in a town of any size, and the whole subject is one demanding serious attention

Another point touched upon by the Commission is the question of water supply Troops are generally supplied from wells, and the drinking water as a rule is excellent, moreover, in the new cantonments a plunge bath is provided, in addition to the regular wash-houses or bath rooms in the barracks What is still wanted, however, is a large bath for each barrack, with a good supply of water always laid on The attention of Government is directed, it is believed, to this point, and the experiment of wells sunk to such a depth as to afford a practically inexhaustible supply having been tried successfully at Allahabad, will be probably sanctioned for other stations The expense is doubtless considerable, varying probably from 2 to 5,000 rupees per well, and the cost of lifting the water will be much heavier, the Persian wheel would not be appli-

cable, and pumps worked by steam or bullock power would be necessary The question of water-supply for native towns is one of much importance and difficulty, and the religious and caste prejudices of the people throw obstacles in the way of affording anything like a common and constant supply But the influence of the authorities should be peremptorily exercised to effect at least the clearance of tanks and their preservation from pollution, while the water for drinking might be separated from that used for other purposes, and where necessary, filtered* into a small reservoir

With the remarks made by the Commission on the dieting of soldiers we have here nothing to do, but the equally important question of providing regular occupation and amusement for their leisure hours, has its Engineering as well as its social aspect All the new barracks have a workshop and reading room provided in

* The following description of a cheap and simple filter proposed for native tanks is extracted from the Asiatic Society s Journal for 1852 —

A is a wall inclosing any space with openings of any kind *at the top only*

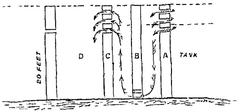
B a second wall with small arched openings *b* below

C is a third wall with openings only at the top again discharging into the reservoir D for the clean water

Now if the spaces between AB, and BC, be filled with any good filtering materials as fine washed sand or the *bujree* used by masons the water which enters through A (being the surface water, which is always the clearest,) † will filter through it downwards beneath B and upwards to C If these spaces be ten feet deep only this gives twenty feet of filtering distance, in every inch of which the water will leave some of its impurities

SECTION OF FILTERING WALLS

TANK 20 FEET AND DRYING TO 15 FEET DEEP



SCALE 20 FT = 1 INCH

A small wall and sluice outside of A would cut off the communication and enable us to clear out our filtering apparatus and re fill it with fresh materials It is probable that no water would require more filtering than this to come perfectly limpid into the reservoir, but if any did so another pair of walls might be added They may be tolerable close, say just far enough apart to allow a man to work in clearing out the material when it requires changing for it is to be noted that the efficiency of this filter depends upon its *depth*, and not on its breadth at all

It is evident that walls may be built to any extent required either merely to inclose a ghat, or a corner of a tank, or across a whole side of it and that arrangements may easily be made for preventing the fouling of the limpid water, when filtered, by those who take it for use

† Some of the holes at A, &c are always supposed to be below the level of the tank when at its lowest level in the dry season

each, besides which a fives court and skittle alley are provided for each regiment Regimental workshops have also been initiated, in which lathes, forges, and such like heavy fixtures should remain as parts of the building, and made over by one regiment to another on its relief In these workshops, carpenter's, blacksmith's, and other work has been executed and sold at a remunerative price, and a late Government order promises to take all necessary barrack furniture and fittings from such shops, but although the experiment has in isolated cases been successful, it is obvious that much must depend on the constitution of each individual regiment, and that it will always be difficult for European labor to vie in economy with that of skilled natives * Still the European in this case has not to live by his labor, and can therefore sell it at a price which under other circumstances would not be remunerative

It is understood that the attention of Government is also directed to a point very much affecting the soldier's comfort, viz, the proper lighting of barracks at night In the barracks at Fort William, gas has been laid on for this desirable purpose, and proposals invited from the Oriental Gas Company to light other stations where Coal gas is available How far Oil gas* can be utilized where the former is not obtainable, is a point still to be ascertained The proximity of most cantonments to large native cities ought to make it worth while to erect expensive works to supply both at each place, provided only the raw material can be obtained

Enough has been said to show that the attention of Government is and has been for some time past earnestly directed to obviate or lesson the evils complained of, and it will also be seen that on many points difficulties have to be overcome which demand serious consideration

* Major Robertson, Superintending Engineer, Indus Tunnel works, states the yield of gas from mustard oil at 70 cubic feet per gallon At the average price of this oil, this would amount to 10 Rs per 1,000 cubic feet. The fuel would cost eight annas and the establishment and apparatus probably Rs 1 8, making the total cost of 1,000 cubic feet of gas, Rs 12 This is about double the average cost of coal gas in the South of England, but would probably be found not dearer than the present cost to Government of the present wretched oil lights

No IX

TRINITY CHURCH, SEALKOTE

Designed and built by LIEUT.-COLONEL J. H MAXWELL, *Royal Engineers*

THE Church and Tower were completed in 1853, at a cost to Government of Rs 41,000*, the additional expenditure, the amount of which has not been ascertained, having been met from private subscriptions In this Church, zinc sheeting was adopted with success in the covering of the roof

The Spire was built in 1861, on Colonel Maxwell's original design, at a further cost of Rs 3,869

No X

NAVIGABLE RIVERS AND CANALS IN THE NORTH WESTERN PROVINCES

[IN 1861, the Government of India (Home Department) having called for a Report on the number and nature of the Navigable Streams in the N W Provinces, the Commissioners of Divisions were asked for information on the subject, and the following Abstract was drawn up from their reports, by the Secretary to Government, N. W Provinces, P W Department]

GENERAL ABSTRACT OF REPORTS BY COMMISSIONERS OF DIVISIONS ON NAVIGABLE RIVERS, IN THE NORTH WESTERN PROVINCES

RIVER GANGES

			Right Bank	*Left Bank*
MEERUT DIVISION —Saharunpore,	-	-	30	"
Moozuffurnugger,	-	-	50	"
Meerut,	-	-	53	"
Boolundshuhur,	-	-	43	"
Allygurh,	-	-	5	"
	Total, -		171	
ROHILKUND DIVISION —Bijnour,	-	-	"	88
Moradabad,	-	-	"	40
Budaon,	-	-	"	95
Shajehanpore,	-	-	"	15
			Total, -	238
AGRA DIVISION.—Furruckabad, -	-	-	60	

			Right Bank	Left Bank
ALLAHABAD DIVISION —	Cawnpore,	- -	70	(Oudh)
	Futtehpore,	- -	65	do
	Allahabad,	- -	85	do
		Total -	220	
BENARES DIVISION —	Mirzapore,	- -	70	,,
	Benares, -	- -	35	,,
	Ghazeepore,-	- -	130	,,
		Total, -	686	283

The whole course of the Ganges in the North Western Provinces, is about 686 miles in length It is navigable throughout the year From the Moradabad district upwards, there is no dry weather trade In the Budaon and Shajehanpore districts, boats of 500 maunds pass up and down, both in the rainy and dry seasons From the Furruckabad district downwards, boats of from 700 to 1,000 maunds can always go up and down freely, as a general rule, however, boats proceeding down-stream with the current in their favor carry heavier cargoes than those which are being tracked up against the stream

In the year 1835-36, a steamer from Allahabad passed up and arrived at Gurhmookhtesur in the district of Meerut, but the experiment was not considered sufficiently successful to encourage further trial

The Commissioner of Agra considers that steam-boats drawing, like those on the Rhine or Elbe, from two and a half to three feet of water, would find no difficulty on this river, if the rocks and shoals were properly ascertained and the channels marked off The river is, however, extremely winding in its course, and its shoals and sands shift with each recurring rainy season

Since the opening of the Ganges Canal the capabilities of this river for navigation have been greatly diminished.

RIVER JUMNA.

			Right Bank	Left Bank
MEERUT DIVISION —	Saharunpore,	- -	,,	65
	Moozuffurnugger,	- -	,,	40
	Meerut,	- -	,,	53
	Boolundshuhur,	- -	,,	42
	Allygurh,	- -	,,	3
		Total, -		213

			Right Bank	Left Bank
AGRA DIVISION —Muttra,		-	,,	77
	Agra,	-	,,	105
	Mynpoory,	-	,,	25
	Etawah,	-	,,	85
		Total,		292
ALLAHABAD DIVISION —Cawnpore,		-	,,	73
	Futtehpore,	-	,,	105
	Banda,	-	105	,,
	Allahabad,	-	,,	65
		Total,	105	213
JHANSI DIVISION —Humeerpore,		-	35	,,
	Jaloun,	-	95	,
		Total,	130	
		Grand Total,	235	748

The Jumna in its course through the North Western Provinces, is about 748 miles in length It is navigable throughout the year for boats averaging from 500 to 1,000 maunds The river in the upper portion of its course has a bed of boulders broken at intervals by strong rapids Below Delhi the bed is generally sandy, presenting no obstacles to navigation beyond a shifting channel and occasional bars and shoals, common to beds of such nature Along this latter portion of its course the main channel, although variable in position, is very uniform in width and depth The river is at its lowest from December to March, presenting in years of average rain-fall, a tolerably uniform depth of one and a half to two feet along its course in the Meerut division If the cold weather rains be plentiful, the depth increases to three or three and a half feet, and the melting of the snows at its source raises it to four feet from the beginning of April to the end of May In the rains the depth is from six to twelve feet

In 1855, the Commissioner of Delhi, with a view of ascertaining the practicability of running an Iron Steam Boat between Delhi and Muttra, despatched an English built boat drawing from three to four feet of water in the middle of June, before the commencement of the rainy season, which reached her destination in perfect safety, demonstrating thereby the perfect practicability of a regular daily water communication by vessels not much exceeding that draught of water

The course of the river in the Muttra district is much obstructed by rocks, but which, the Commissioner thinks, could easily be removed by a few blasting operations The depth here is from three to four feet in the dry months After leaving Muttra, the river in the Agra district is considerable more tortuous in its character, the depth in the dry months not more than one and a half feet, and in the rains from twelve to fourteen feet The Magistrate of Agra, proposes to straighten and reduce the river by cuttings wherever it is most tortuous, for instance, in the Bah and Futtehbad pergunnahs The bed of the river here is, however, very deep and its banks rocky, and it is apprehended that the work would be costly beyond the value of any object to be gained

For some years a Company of Sappers and Miners was employed in the Etawah district, in clearing away the rocks and obstacles that imprison the Jumna a few miles below Shergurh, near Bhuduk, but much yet remains to done to make the river safely navigable for a steamer, with this exception, the Jumna in its entire course through the Etawah district, would be navigable by any steamer not above ninety or hundred feet long, and not having a draught, when laden, of more than four feet, inclusive of keel

The navigation of the Jumna in the Allahabad division is more difficult than that of the Ganges, the bed of the river in several places is crossed by ledges of rock and beds of kunkur and clay, by which the the depth of water is reduced and the navigation rendered dangerous Boats of 500 maunds can navigate the river in the Allahabad district, and steamers up to Allahabad

In the Humeerpore and Jaloun districts, the river is sufficiently deep to allow steamers of the same draught as now ply between Calcutta and Allahabad, being used The quick-sands are not so common about here, and the river is free from stumps of trees, which are so injurious to river navigation With a small outlay, the Deputy Commissioner of Jaloun thinks, that the river could be cleared for the navigation of flat bottomed steamers, such as are used on the Indus

The Commissioner of Agra is of opinion that both the Ganges and the Jumna may be made infinitely more useful for the purpose of navigation, than they have hitherto been He believes that the class of steam boats, best adapted for dealing with the sand, shoals, and shallows of these streams has never yet been introduced into India Vessels

drawing from one foot to eighteen inches of water, exceedingly strong, and yet carrying a large bulk of cargo, are in daily and nightly use in Europe, and on the rivers of North America, and with a proper establishment of river pilots and some application of Engineering skill, the Commissioner sees no reasons why both these rivers may not be traversed by steamers with safety, both by day and night

---

RIVER SOTE OR YAR WUFADAR

			No of miles
ROHILKUND DIVISION —Moradabad,	-	-	45
Budaon,	-	-	65
Shajehanpore,	-	-	15
	Total,	-	125

The total length of this stream is 130 miles It takes its rise at Amroha, in zillah Moradabad, and flows into the Ganges in the district of Shajehanpore At present it is used for crafts of 100 maunds tonnage in the rains, and 50 in the early part of the dry weather The Commissioner thinks that it would be worth while having professional opinion as to its capabilities of navigation for about forty miles of its course as far as Budaon

---

RIVER RAMGUNGA

			No of miles
ROHILKUND DIVISION —Bijnour, -	-	-	35
Moradabad,	-	-	55
Rampore,	-	-	20
Bareilly,	-	-	60
Budaon,	-	-	15
Shajehanpore,	-	-	25
			210
AGRA DIVISION —Furruckabad, -	-	-	20
	Total,	-	230

This river, in the earlier part of its course from the foot of the hills, for about 200 miles, is not used even in the rains for navigation Lower down from Bareilly for eighty miles, it is much used during the rains by boats of 1,000 maunds, and at a drier period, for boats of 500 maunds But from October to July navigation ceases It is a shifting and un-

manageable stream, and would not admit of a remunerative outlay to improve its channel

RIVER DEOHA, OR GURRA

		No of miles
ROHILKUND DIVISION —Pilleebheet, -	- -	40
Bareilly, -	- -	30
Shajehanpore,	- -	50
	Total, -	120

This river rises in the Kumaon hills and enters the Ramgunga in Oudh, just before that river falls into the Ganges During the rains, boats of 250 to 300 maunds navigate from Pilleebheet, and of 500 maunds from Shajehanpore It is not navigable during the dry weather

RIVER CHUMBUL

		No of miles
AGRA DIVISION —Agra,	- - - -	45
Etawah,	- - - -	43
	Total, -	88

This river takes its rise near Mundee in Malwa, within fifteen miles of the Nerbudda, and falls into the Jumna below Etawah It is reported to be used *infrequently* by small boats, but can hardly be called navigable In the rains it is a furious torrent, and in the dry months so obstructed by rocks as to be only deep enough in its channel for small boats Engineering skill might make its lower course navigable in the cold months

RIVER TONSE

		No of miles
ALLAHABAD DIVISION —Allahabad, -	- -	40

The Tonse is navigable for about twenty miles from its mouth, but there is a bar at the junction with the Ganges, which forms a serious obstacle to the entrance and exit of boats For the short distance in which, under the most favorable circumstances, this river could be employed for the transport of goods, any outlay in its improvement would be unproductive

RIVER NERBUDDA

		No of miles
SAUGOR DIVISION —Mundla,	- -	45
Jubbulpore,	- - -	78
Nursingpore,	- - -	83
Hoshungabad,	- - -	120
	Total, -	326

This river is only navigable in short patches in the rains, owing to the fall of the river being in steps It rises at Umerkuntuk, 3,300 feet above the sea, in the Sobagpore Pergunnah, in the Rewah territories, and falls into the sea at Baroche, in the Bombay Presidency One of the selections from the Bombay Government Records describes the physical character of the river

RIVER GOGRA

		No of miles
GORUCKPORE DIVISION —Goruckpore,	- -	150

Steamers can ply only in the rainy season without fear of being grounded Large native boats of 1,000 or 1,500 maunds can go up and down the river in the hot season

RIVER KOANA

		No of miles
GORUCKPORE DIVISION —Goruckpore,	- -	70

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can pass in it The river flows through the most populous and productive part of the district

RIVER RAPTEE

		No of miles
GORUCKPORE DIVISION —Goruckpore,	- -	130

In the rainy season large native boats of more than 2,000 maunds can go up and down the river, but in the hot weather boats of about 500 maunds only can navigate it.

River Chotee Gunduk

		No of miles
Goruckpore Division —Goruckpore,	-	110

Navigable by boats for eight months It almost dries up during the hot season in some places Many large bazars are on this river, and the neighbouring country productive When the season affords a sufficient depth of water there is very considerable traffic down this stream

River Burree Gunduk

		No of miles
Goruckpore Division—Goruckpore,	-	75

In the rainy season large native boats of 400 or 500 maunds can go up and down this river Steamers can also navigate in the rainy season

River Dhamala

		No of miles
Goruckpore Division —Goruckpore,	-	15

Boats of 500 maunds navigate this river in the rainy season In the hot months it is very shallow

Rivers Boorhee, Raptee and Bangunga

		No of miles
Goruckpore Division —Goruckpore,	-	45
Goruckpore,	-	25
Total,	-	70

Both these streams are natural canals in which water remains all the year round, even during the dry season There is always a moderate current in them

River Rohin

		No of miles
Goruckpore Division —Goruckpore,	-	55

Wood rafts come down this stream from the jungles, also grain canoes The river throughout its entire course flows past forests and wastes, and having no bazar near its banks, it is not navigated by boats

River Surgoor, or Tounse

		No. of miles
Benares Division.—Azimgurh,	-	70
Ghazeepore,	- -	33
	Total, -	103

Can be navigated in the rainy season by boats of 500 maunds all through the Azimgurh district. Boats of 1,000 maunds can likewise ascend in the rainy season to a distance of thirty miles from its mouth.

River Goomtee

		No. of miles
Benares Division.—Jounpore,	- -	55
Ghazeepore,	- -	10
	Total, -	65

Can be navigated in the rainy season by boats of 1,000 maunds to beyond Jounpore, and by boats of 200 maunds all through the division at all seasons of the year.

River Saee

		No. of miles
Benares Division.—Jounpore,	- -	45

Can be navigated only in the rains by boats of 100 maunds.

River Burna

		No. of miles
Benares Division.—Benares, -	- -	28

Can be navigated in the rainy season to a distance of thirteen miles from its mouth, near Benares, by boats of 200 maunds.

Ganges Canal.

		No. of miles
Meerut Division.—Saharunpore,	- -	33
Moozuffurnugger,	- -	35
Meerut, -	- -	50
Boolundshuhur,	- -	35
Allygurh,	-	64
	Total, -	217

		No. of miles
AGRA DIVISION.—Mynpoory,	- -	62
Furruckabad,	- -	40
	Total, -	102
ALLAHABAD DIVISION.—Cawnpore,	- -	42
	Total, -	42
MEERUT DIVISION.—Moozuffurnugger,	- -	16
Meerut, -	- -	35
Boolundshuhur,	- -	55
Allygurh, -	- -	20
	Total, -	216
ROHILKUND DIVISION.—Budaon,	- -	7
AGRA DIVISION.—Mynpoory, -	- -	15
Furruckabad,	-	15
	Total,	168
MEERUT DIVISION.—Allygurh, -	-	25
AGRA DIVISION.—Muttra, -	-	5
Mynpoory, -	- -	49
Etawah, -	- -	48
ALLAHABAD DIVISION.—Cawnpore, -	-	50
	Total, -	177

EASTERN JUMNA CANAL

		No. of miles
MEERUT DIVISION.—Saharunpore,	- -	54
Moozuffurnugger,	-	30
Meerut, -	- -	47
	Total, -	131

No. XI.

ARCHING OF THE MORHUR BRIDGE—BENGAL.

From CAPTAIN C. J. MEAD, *Executive Engineer, 2nd Division, Grand Trunk Road, to the Superintending Engineer, Behar Circle.*

17th July, 1863.

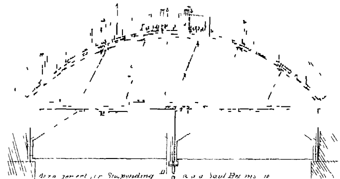
SIR,—I have the honor to report for record in your Office, and, should you think fit, the information of the Chief Engineer and Government, (your presence on the spot, and my having continually had the advantage of your personal advice and instructions, renders it unnecessary I should do so for your information,) that we have completed the arching of the centre section of six arches (74 feet span) of the Morhur Bridge, and struck the last centre on the 10th instant. I annex in a Tabular Form a Memorandum, showing the dates on which we commenced, completed, and struck each arch, and the amount of sinking at the crown, on removing centres.

I annex a drawing of the centres we used, which proved perfectly efficient, and a small sketch showing the somewhat unusual method adopted to strike the centres, which answered so well, and is, I have reason to think, so superior to the usual method of wedges, that I venture to add a brief memorandum describing it in detail.

The arches have been turned in five concentric rings, each one brick, or nine and a half inches thick, laid alternately header and stretcher, greater care being taken to set them with as fine joints as possible, and a perfect bond in each ring being obtained by the use of two and a half bricks moulded for the purpose in each alternate course. The bricks were set in excellent kunkur lime mortar, ground under stone rollers

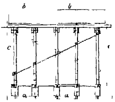
MORHUR BRIDGE CENTRE

Elevation

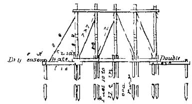


Arrangement for Suspending Centre after removal of Lower Supports rotted
a a a Saul Beams
b b b
c c c 3/4 Iron bolt suspension rods

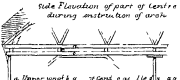
Transverse Section on the line A B



Transverse Section on the line C D

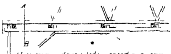


Side Flevation of part of Centre during construction of arch

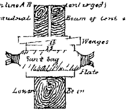


a Upper longl b
b Lower do
c Block

Side Flevation of part of Centre just before striking



Transverse Section on line A B (enlarged)



Plumb Bob

on the bank of the river, and conveyed mixed in small tip trucks made for the purpose along our tramway to small tanks opposite to each pier, from whence it was hoisted in boxes over wooden pulleys to the tops of the piers, as required by the women in attendance on the masons The bricks were similarly brought from the brick field, a distance of about half a mile, in trucks, from which they were stacked in tanks full of water until wanted, and thence passed from hand to hand by a line of women seated on ladders placed against the cut-waters of the piers

As will be noticed from the Tabular Statement annexed, the amount of sinking at the crown, on removal of centres, has been, I think exceptionally small in arches, Nos 5, 6, 7, 8 and 9 I attribute this to the excellent material used, and particularly to the very perfect form of our bricks, which (moulded on tables on the English stock moulding system, as introduced by Mr Power, of the East Indian Railway, at the Soane Bridge works, and which I succeeded in introducing here by the assistance of a trained moulder whom his successor kindly obtained for me) are, I think I may say, equal, if not superior, both in strength and shape to any ever made in Bengal No 10 arch sunk much more, indeed so much more than had been anticipated from our experience of those struck previously, that, not having allowed sufficient space above the blocks on which the centre was to rest after striking, it was necessary to lower the centre a second time, and, as might have been expected under the additional motion, slight cracks showed themselves for a few feet on each side of the crown between the first and second, and second and third rings, of which the arch is composed These, however, are so trifling that they are imperceptible after pointing, and I believe, quite immaterial with reference to the strength and stability of the arch, and are the only cracks or flaw of any kind which exist in our work, consisting of 58,000 cubic feet of brick masonry, all executed between the 15th April and the 22nd June

There being some fear that if we attempted to remove all the centres, the setting in of the rains, producing the usual heavy floods in the river, might cause damage, and perhaps, loss of some portion of these valuable framings, which took a long time and much labor to construct, I gladly adopted and carried out a suggestion of yours, and have suspended the whole of the upper portion of the centres to the

arches by means of temporary cross beams above the arches and below the horizontal beams of the centres, connected with vertical bolts of $\frac{3}{4}$-inch rod iron, and have only removed the vertical standards and struts which would have been in the waterway. Each complete centre, consisting of five trusses, with the lagging and its coat of plaster, weighs about 43 tons, and is supported by twenty-four drop bars of $\frac{3}{4}$-inch bolt iron, (to avoid any risk from faulty welds, every drop bar has been tested with a strain of $2\frac{1}{2}$ tons, it has only 1·8 tons to carry, while its calculated breaking load would be 44×20 tons $=$ 8·8 tons,) and by this most convenient arrangement the whole of our centres remain in place for the rains under the arches which have been turned on them, (which form a first-rate roof for their protection from the weather,) and are most conveniently placed for removal and re-erection when we commence work in November.

This work has been a most anxious one, being a larger job than I or any member of my establishment had ever seen executed before in India, (I believe they are the largest arches that have been completed in Bengal up to date,) and one which it was necessary to complete in a given and short time. I have great pleasure in bringing to your notice, and shall be obliged by your reporting to the Chief Engineer, the conduct and exertions of the Establishment employed—Assistant Engineers Mr. J. Luff and Mr. Mansfield, Assistant Overseer Abbott, and Sub-Overseers Hutton, Thompson, and Burney, while I would especially record my sense of the services of Assistant Engineer Mr. Luff, who has been in immediate charge of this work, and to whose professional knowledge, constant attention to details, and real devotion to his duty, I consider the chief portion of our success due.

MEMORANDUM ON THE METHOD ADOPTED IN STRIKING THE CENTRES OF THE MORHUR BRIDGE, AT SHERGHOTTY, IN 1863.

In arranging the details of the centres for the arches of the Morhur and Booriya Bridges at Sherghotty, after designing the main details of the trusses to carry the weight of the arches, the arrangements for striking them, after the arches were keyed, appeared important. While, considering the arrangements to be made, Captain Mead came across an interest-

ing account (in the Supplementary Volume of Weale's Bridges, an extract of which is annexed for reference) of a method which had been adopted in striking the centres of a Bridge over the Creuse, at Port-de-Pile, on the Orleans and Bordeaux Railway, where the weight of the centres, and of that portion of the arch resting on them, was transferred after keying, from blocks to sacks filled with sand, the mouths of which being opened simultaneously, the sand running out lowered the centres gradually and uniformly without effort, thus avoiding the difficulty of lowering uniformly by striking back a number of wedges simultaneously, where it frequently occurs that some wedges suddenly slip and fly back at once, while others are jammed hard and require much trouble and heavy blows to start them.

These difficulties appeared to be more likely to occur in striking a large centre in India than in Europe, where some little reliance may be placed in the exercise of a little intellect by every workman, while at Sherghotty we could not expect the exercise of any by those employed, with exception of the three or four Europeans who could be collected to superintend.

A trial having been satisfactorily made by wedging up and lowering a platform of timbers loaded with a mass of stone, it was decided to adopt a modification of the plan described, and our arrangements were consequently made as follows:—

The centres were designed with double longitudinal beams, the lower one carried on the posts and struts forming the supports of the centre, and the upper one forming the tie to the series of triangles forming the upper portion of the centres (*vide* drawing). This upper beam rested on the lower at a distance of 12 feet through blocks 8 × 8 × 12 inches of soft easily splitting wood (*dhow*). When the arch had been keyed, a strong sack made of double coarse country canvas (*tat*) made as a tube, filled with dry sand and tied with string at both ends, was introduced between these two beams close to each block, a plate of stout plank, (12 × 15 × 2 inches) being placed above and below to distribute the pressure fairly over the bag, and finely tapered wedges in pairs were driven between the upper plate and the upper longitudinal beams with heavy mallets, until the weight of the centres in lieu of resting on the blocks, was borne by the sand bags, and the blocks were so far loosened that they could be easily driven out of their places with a few blows of the mallets. Any individual blocks which could not be thus relieved, or were jammed, were

split out by carpenters, but this was not found necessary in more than two or three cases The blocks were then re-introduced into their places, but laid on their sides instead of on end, thus leaving a space of four inches between their upper surfaces and the lower side of the upper longitudinal The whole centres now rested on the bags, of which eight supported each truss, or forty the complete centre Eighty ordinary coolies were now brought up, two to each bag, (one taking charge of each mouth,) and two or three Europeans posted among them to see, and report, each order obeyed The word was then successively given—*first*, to untie the up-stream mouths of each bag but not to allow any sand to escape, *second*, to untie the down-stream mouths, *third*, to allow the sand to run out of the bags, when the whole of the centre sank gradually and steadily until it again rested on the blocks placed to receive it, leaving the arch unsupported

It was really a very pretty sight to see the large mass of complicated timber framing 74 × 24 × 16 feet, and weighing nearly 50 tons, besides the portion of the weight of the arch of masonry resting on it, gradually subside, with a motion so slow and smooth that it was perfectly unnoticeable even while standing on it, except by the separation between the lagging and the arch, and the approximation between the longitudinal beams, so uniform was the motion, that not even a creak was heard from any joint of the frame, and the time occupied by the movement did not exceed one minute The amount of sinkage at the crown of the arch was accurately noted by means of two heavy leaden plummets weighing 8 to 10 lbs each, and having a small brass scale attached, one of which was hung from either side of the crown by an iron wire, and rested in a tub of water below to check any oscillation of the plumb bob, consequently the depth to which the scale was immersed before and after striking, being carefully noted, the difference showed the exact amount the crown of the arch had sunk, this measurement was further checked in some arches, by observing a point on the key of the arch from a distance, through the telescope of a theodolite

C J MEAD

Extract from an Account of the Bridge at Port-de-Pile over the Orleans and Bordeaux Railway

(Weale's Bridges, Supplementary Volume, page 109)

"A very ingenious mode of striking the centres was introduced in the bridge of the Port de Pile for the purpose of easing them gradually and without shocks from which cause such serious inconveniences arise in the generality of cases In many bridges it has been found impossible to drive back the wedges towards the middle of the span, even when a sheet of metal has been interposed, owing to the enormous insistent pressure It becomes often necessary in such cases to place narrower wedges by the side of the original ones, and to cut away the latter The centre then drops, suddenly, perhaps, communicating its motion to the masonry, and, moreover, as it is impossible to cut away the wedges with perfect regularity, the centre becomes deformed in its descent, or one rib of a centre may be loosened before the rest, either causing distortions of the masonry, or rendering it necessary to restore that rib to its place by screw-jacks to relieve the others still in their original positions

"As M Boudemoulin observed, the difficulty of producing movement in the wedges arises from the fact that the fibres of the wood in the inclined faces penetrate into one another from the effect of their load, and the alternations of dryness and moisture they are exposed to The force which can be exerted upon them at the moment of striking the centres is never sufficient to overcome the friction arising from these causes

"Experiments were tried to ascertain whether the difficulties attached to striking the centres might be obviated by placing the ribs upon fir sills during the execution of the work, the intention being to place wedges by their side at the moment of easing the centres, and cut away the sills, so as to leave the ribs upon the wedges, which were then to have been lowered The maximum weight able to be brought upon one pair of wedges was 45 tons in the bridge of the Port de-Pile

"Wedges of oak, whose sides were inclined in the proportion of 1 in 3½, the faces being well greased being intercalated, were placed under an hydraulic press, and exposed to an action equivalent to a weight of 50 tons, yet they did not slide upon one another even when struck with a large hammer Other wedges of a compound nature, in three pieces, the top and bottom ones having one face horizontal, and the middle piece two inclined faces of 1 in 4, were tried without producing a more favorable result The inclination of the middle piece was carried as far as 1 in 3 on each side, but still there was no spontaneous movement

"Sacks filled with sand were then placed under the press, the cloth of which they were made being very strong, and in the experiment the sand was dried The flow of the sand through the necks took place with the regularity of a clepsydra, and it was at any moment stopped by merely tightening the string The weight was increased to 60 tons, but was as perfectly under control as before, even with an opening in the sack of 1 foot 4 inches long, the flow was regular, and no sudden fall occurred

"In consequence of the success of the experiments upon the sand in the sacks, the system used in this bridge was decided upon. It consisted in placing immediately over each point of support of the centres, blocks of fir on end, about 1 foot 4 inches square, the total number being 36 per arch. When it was desired to lower the centres, sacks (of common strong cloth made open at both ends, and merely closed by a strong cord) filled with sand, were placed close against these blocks. The sacks to be placed at the points where the weight was greatest were double, and in all cases they were bound round the middle by a cloth to increase the resistance in that portion. A small tube of cloth filled also with sand was introduced in the centre, to form as it were, a nucleus. The sacks when completed were thus cylinders of about 1 foot 2 inches in diameter, by about 1 foot 4 inches long. They were placed upon a thin plank, and wedged up to the under sides of the sill by fir wedges.

"The upright blocks were then cut away gradually, and the weight was brought upon the sand bags. The first movement was produced by the compression of the sand, which was observed to be about 1 inch. The mouths left at the ends were then opened, and care was taken to regulate the flow of the sand, so as to obtain a regularity of descent by means of a small wood frame at the mouth. As soon as the centre became detached from the arch, the ends of the sack were opened to their full extent and the flow of the sand expedited, so as to lower the whole centre about 1 foot, at which height it might either be left, or a series of wedges of the remaining distance between the sill and the supports might be introduced, to enable the sacks to be withdrawn and the descent continued.

"It was found that dried sand pressed very closely upon the sacks occasionally destroys them; with sand in its ordinary state, they were found to resist better, but the escape was also less easy, for the pressure tended to make the sand aggregate. As an additional precaution, small blocks, varying in height as the centres were lowered, were introduced to receive them in case of any sudden depression of the sacks; but in no case were they ever brought into action, so perfectly did the system answer. Indeed, during the whole time the operation of easing the centres was going on, no noise or creaking of the wood was heard, and it was only by measuring the distance between the sill and the top rail of the framework upon which the centres rested, that the lowering of the former could be perceived; nor could the separation of the centre from the arch be distinguished without observing the latter very closely. It was thus evident that the system of easing the centres followed in this instance allows them to subside gradually, so that the voussoirs cannot assume abruptly any movement; and, inasmuch as all the bearing points sink gradually, the pressures are uniformly distributed. The system was applied for the three arches of the bridge of the Port-de Pile, and also for four arches of a bridge over the Vienne, on the same railway, with perfect success; so that a sufficient number of practical experiments confirm its merits. The expense is also very insignificant, for the sacks when single, only cost 3*s.* 4*d.*, and when double, 6*s.* 3*d.*, with some slight repairs the same sacks served for the seven arches."

NT SHOWING THE DATES OF COMMENCEMENT OF MASONRY, KEYING CH, AND THE STRIKING OF CENTRES, WITH THE AMOUNT OF SETTLE- OF EACH OF THE SIX ARCHES COMPLETED, OF THE MORHUR BRIDGE 63-64

(*Span* 74 *feet, versed Sine* 15 *feet*)

Date of mmencement of Masonry	Date of keying the last ring	Date of striking centres	AMOUNT OF SETTLEMENT OF ARCHES		
			At once	During next 24 hours	Total
			inch	inch	inch
April 20th	June 9th	June 9th	$\frac{5}{8}$	$\frac{1}{16}$	$\frac{11}{16}$
,, 15th	,, 3rd	,, 5th	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$
,, 16th	,, 7th	,, 7th	$\frac{5}{8}$ bare		$\frac{5}{8}$
,, 18th	,, 9th	,, 10th	$\frac{7}{8}$		$\frac{7}{8}$
,, 27th	,, 22nd	July 10th	$\frac{1}{2}$	$\frac{1}{16}$	$\frac{9}{16}$
,, 24th	,, 20th	June 20th	$2\frac{3}{4}$	$\frac{1}{8}$	$2\frac{7}{8}$

C J MEADE

MEMORANDUM BY THE SUPERINTENDING ENGINEER

arded to the Chief Engineer with two drawings and three copies ograph The undersigned has nothing to add to the Executive er's Report, he has been present throughout, and has witnessed tions of all hands in executing this work

bricks used throughout were excellent, the mortar very good

The way the arches have been turned in $9\frac{1}{2}$-inch* concentric as ordered by Superintending Engineer, and the result is per- satisfactory, there is no brick-work in all India superior to these six arches, as is proved by the very trifling subsidence on g the centres, the one arch that sunk $2\frac{7}{8}$ inches was struck on after completion, for owing to a failure in the supply of Nos 9 and 10 had to be stopped for half of May, and they

* One brick on-end, and two on edge, alternately

were only proceeded with vigorously in June, but what is a sinkage of $2\frac{7}{8}$ inches in an arch of 74 feet span, the rise being 15 feet?

The mode adopted of supporting the centres on the arches has proved very satisfactory, and a vast amount of time and labor has been thus saved Everything has been done by Captain Mead systematically and with care, and complete success has attended all his arrangements The services of this officer and of Mr Assistant Engineer Lutt are very strongly recommended to the notice of the Chief Engineer, few can understand, but those on the spot, the amount of exposure and anxiety they have both undergone during an unusually hot season

Mr Assistant Engineer Mansfield has been present throughout the arching, and had his share of exposure and hard work, and has proved himself an admirable assistant, the Overseers named have worked cheerfully and well, and Superintending Engineer hopes the result now reported will be considered altogether satisfactory, and creditable to the Public Works Department

W MAXWELL

20th July, 1863

No XII

EUROPEAN INFANTRY BARRACKS, NOWSHERA—PUNJAB

Erected in 1855, *by* LIEUT (*now* CAPT) F S TAYLOR, R E

[THESE Barracks are modifications of these originally designed for the Punjab cantonments, each building containing a half, instead of a whole, Company, and the wards being separated from each other by doors instead of archways, so as to form complete rooms for 12 men each The frame work of the roofs is of iron, the floors are of slate, procured from the neighbouring Khuttuk hills It is believed that no Barracks, as yet constructed in India, are better built or surpass these in comfort and healthiness —ED]

SPECIFICATION

Each Barrack to accommodate one company, consists of two wings connected by a passage 30 feet long

In each wing there are four main rooms, 42 × 24 feet, with a reading room or workshop, 26 × 16 feet, at one end, and four rooms 22 × 14 feet, for the accommodation of the Sergeants at the other end. The inner enclosed veranda is twelve feet wide, with double doors The outer veranda is open, ten feet wide, the archways being eight feet span

The main walls are twenty-two feet in height from the level of the floor to the top of the stone templet, which receives the shoe of the iron trussed frames of the main roof The roof is on a pitch of thirty

degrees, and is formed of large Grecian tiles set in mortar, over twelve inch square bricks, two inches thick

The walls of the inner veranda are sixteen feet high from the level of the floor to the bottom of the iron beams The roof is flat, formed by arching from beam to beam the underside being plastered, and the upper covered with one inch fine terrace, the spandrils being filled in level

The walls of the outer veranda are twelve feet nine inches high The roof being flat, pucka terrace, supported on deodar kurries, scantling 5 × 4 inches, placed nine inches apart

The main walls are two and a half feet thick up to the inner veranda roof, and two feet above this

The plinth is three feet in height, and has one off-set of three inches, and the foundation, which is two feet deep, has two off-sets, each three inches

The inner veranda walls are two feet thick up to the outer veranda roof, and one a half above this

The plinth and foundation have similar off-sets to the main walls

The outer veranda walls are two feet thick up to the springing of the arches, and one and a half feet above this The plinth is one foot lower than the interior floors, and the foundation is only one and a half feet deep, with similar off-sets to the other walls

The masonry of the foundation and plinth is of slate stone and mortar, the latter having equal proportions (by measurement) of stone lime, soorkee, and river sand

The masonry of the superstructure is throughout of burnt brick and lime cement, in proportions as above

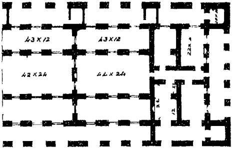
The whole of the interior of the buildings is plastered with sand plaster, having washed sand and lime, in equal proportions (by measurement)

The exterior of the whole building is pointed, with exception of the cornices, which are plastered with a cement formed of lime and soorkee, in equal proportions, well beaten and consolidated, two feet at the bottom of the outer walls and the outer face of the plinth are plastered similarly to the cornices

The whole of the flooring is formed of slate slabs set in mortar, over two courses of bricks laid flat, earth being first filled in and rammed to obtain the necessary height

RA BARRACKS.

nmodate one Company)



Scale of feet for Plan

0 9 10 20 30 40 50 60 70 80 90 feet

Scale of feet for Section

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 feet

d up

The whole of the doors are pannelled, the frames being two inches thick, the windows, where practicable, are hung on the centre so as to open when required

The punkahs are hung from iron rods at a height of fifteen feet from the floor For the purpose of ventilation the ridge of the main roof is perforated along its entire length, and in the inner veranda the iron tubular beams are left open at the extremities to admit a current of air through them into the building

---

Abstract of Estimate

		RS	A	P
4,939·5	Cubic feet slate stone masonry in foundation and plinth, at Rs 18 per 100,	8,269	1	9
942·5	Brick-on-edge masonry in plinth, at 20 Rs per 100,	188	8	0
1,27,190	Cubic feet pucka brick masonry in superstructure, at Rs 19 per 100,	24,166	1	7
9,200·9	Cubic feet pucka arched masonry, at Rs 21 per 100,	1,932	3	0
12,028	Superficial feet main roofing, at Rs 40 per 100,	4,811	3	2
11,583	Superficial feet inner veranda roofing on iron beams, at Rs 35 per 100,	4,054	0	10
2,751	Superficial feet flat pucka roof reading and sergeants' rooms, at Rs 50 per 100,	1,375	8	0
13,970	Superficial feet outer veranda roofing, at Rs 28 per 100,	3,911	9	7
1,42,806·89	Superficial feet pucka plaster, at Rs 3 8 per 100,	4,880	11	10
1,18,100	Superficial feet white washing, at 8 annas per 100,	590	8	0
60,197	Cubic feet filling in under floors, at 6 annas per 100,	225	11	9
34,161·25	Superficial feet stone flooring, at Rs 20 per 100,	6,832	4	0
19,880	Superficial feet outside painting, at Rs 2-4 per 100,	447	4	10
6,919	Superficial feet doors and windows, at Rs 80 per 100,	5,535	3	2
74	Punkahs, with iron suspension rods, ties, &c, at Rs 15 each,	1,110	0	0
768	Superficial feet shelves, at 4 annas per foot,	192	0	0
192	Accoutrement pegs, at 3 annas per 100,	36	0	0
90,497	Cubic feet filling in round barrack, at 6 annas per 100,	339	5	10
	Total,	68,997	5	4
	Contingencies, at 5 per cent,	3,449	13	10
	Grand Total,	72,447	3	2

MEMORANDUM

The cost of the carriage of iron roofing from Lahore to Nowshera is included in the estimate, but the price of the iron work is not known

Forty-two trussed frames and 184 iron beams are used in each barrack

The masonry of the cornices is not set down as a separate item, but included in the masonry of the building

F S TAYLOR

No XIII

GOODWYN'S TILED ROOFING

From Superintending Engineer, Central Provinces, to all Executive Engineers

Gwalior, 6th December, 1850

GENTLEMEN,—It being very important that an improvement should take place in both the manufacture of roofing tiles, and the method of tiling, I have the honor to draw your earliest attention to the matter, trusting to a zealous co-operation in the endeavour to effect so very desirable an end I need scarcely point to the causes which induce me to attempt a reformation in this material, they are, however, briefly these —

1stly They are not sufficiently substantial to resist the action of winds, and the disturbing propensities of kites and crows, whilst it is a matter of difficulty to repair a broken tile on a roof, without either disarranging or fracturing others, on account of their brittleness and lightness

2ndly From their small size, they require the intervention of a bamboo frame, tied with string, which, when it begins to decay causes settlement of the tiles and leakage

3rdly If laid in mortar, the consumption of that material is far too great in proportion to the surface covered by the tiles, whilst if laid in mud, which is constantly the practice, a nest of white ants is carried up into the roof to destroy the frames and timber, besides, the mud shrinks in drying, and is of no use as a cement

4thly They are so carelessly made, from the fact of the clay not being either properly tempered and kneaded, and the tiles themselves not being properly moulded and formed, that they frequently absorb water and very nearly melt, whilst rain in high winds is driven through every interstice

Here are surely causes enough for the introduction of a material, which shall be not only serviceable as a permanent covering, but relieve you from the constantly recurring necessity of repairs which, when executed, are flimsy, easily destructible and unsatisfactory.

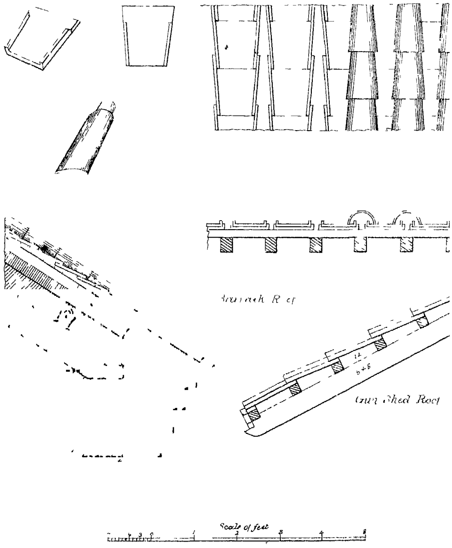
The kind of tiles that I wish to introduce, is a large and substantial flat tile, with raised edges, the joints between which are covered with a semi-cylindrical tile precisely such as were in use by the Romans. I have successfully made them both in Calcutta and Lahore, and there is no reason why they should not be generally adopted. The accompanying sketch, will show the nature of the tiles, and the method of tiling. Being 12 inches wide at the upper end, they are laid either on small rafters placed at 1 foot between centres, or on battens with similar intervals.

For buildings, where a moderate temperature is required, they may be placed over a layer of the common flat tile, $1\frac{1}{2}$ or 2 inches thick, with a thin bed of mortar intervening; but in buildings of less pretension they should be laid alone on the wood-work, with cemented joints. The eaves may be finished off either by upright eave tiles in cement, or wooden plates let into the end of the rafters; for ornamental purposes, by a plain Tuscan cornice, the corona well projecting and undercut, to throw off the rain water clear of walls, or by a gutter and simple fascia, where well preserved wood or metal is available.

The clay required for tiles should be strong and more tenacious than that required for brick, *i. e.*, it should not have the same proportion of sand in it, it should be dug sometime before moulded, and all foreign substances likely to destroy the tile when burning, carefully extracted. As a pug-mill is seldom available, the clay should be cut, slashed, turned with phowrahs, watered, and left in a heap for some time, covered with brushwood if possible, to prevent its getting too dry. Before moulding it should be kneaded and well tempered, reducing it to a uniform texture. It will be necessary, I think, to use moulds, to form the flat tile, and the freshly moulded tile should be $1\frac{1}{8}$ inches thick all over, that it may dry to about $\frac{15}{16}$th or $\frac{7}{8}$th inch thick. Great care should be observed in the drying; a moderate sun, or (when that is powerful) almost shade being requisite to prevent distortion. They may be burnt occasionally with large bricks, but I think a pottery kiln is better.

H. GOODWYN.

GOODWINS TILED ROOFING



From CAPTAIN J N SHARP, *Exec Engineer, Lahore Division, to* LIEUT.-COLONEL G B TREMENHEERE, *Superintending Engineer, Punjab Circle*

SIR,—I beg to forward you the following report on Colonel Goodwyn's Tiled Roofing, as at present constructed, a copy of which I beg you will be good enough to forward to him agreeably to his request

---

DETAIL OF CONSTRUCTION

Deodar battens, 3 × 2 inches are nailed on the purlins at twelve inches from centre to centre, on which are laid twelve-inch square tiles, two inches thick, well fitted, cemented at the joints, and pointed underneath a layer of good mortar about one and a half inches thick is then laid, in which the pan-tiles are well embedded at regulated intervals, which are filled up with mortar, and over them the round tiles carefully fitted and set The eaves terminate in a masonry cornice, as shown in the figure, and the ridges are covered in with round and flat tiles, expressly made for the purpose, gable ends have been adopted as better suited to this description of tiling, the slope of the roof 28° After the tiles had been laid, the joints were carefully pointed, and the roofing kept well wetted during its construction, and for ten days afterwards, by means of watering pots used from the ridge of the building, not in a stream down the roof, but merely sufficient to keep the whole saturated

(1) WEIGHT OF TILING PER SQUARE FOOT

	lbs
One square tile, 12 × 12 × 2 inches, - - - -	19
One pan-tile, - - - - -	6
One round tile, - - - - -	4
One and a half inch of mortar, - - -	12
Total, -	41

(2) DETAIL OF LABOR AND MATERIALS PER 100 SQUARE FEET

	Labor		R	A	P
½	Mate mason, @ As	5	0	2	6
10	Masons, ,,	4	2	8	0
½	Grammie, ,,	2½	0	0	10
2	Bheestees, ,,	2½	0	5	0
¼	Carpenter, ,,	4	0	1	0
½	Mate coolie, ,,	2½	0	1	4
14	Coolies, ,,	2	1	12	0
1	Coolie, ,,	1½	0	0	6
	Establishment,		0	2	6
	Total Rs,		5	2	7

	Materials	R	A	P
100	Square tiles, @ Rs 25 -	2	8	0
110	Pan tiles, } ,, 15 -	3	4	0
110	Round tiles, }			
25	Maunds of kunkur lime, @ Rs 15 per 100, -	3	12	0
2½	Stone lime, @ Rs 1, -	2	8	0
	Scaffolding, &c, -	0	6	0
	Total Rs -	12	10	0

The labor appears high, but so is all labor at this station, wages are high and very little work done The tiles are exceedingly well made by contract at the above rates, paid for as counted in the building, allowing ten per cent for breakage, the kunkur lime is of very inferior quality, and will admit of no admixture with pounded bricks or gravel, and for want of mortar-mills to grind it is only sifted the refuse used on other works

Under ordinary circumstances this tiling would not cost more than two-thirds of the above

COMPARISON OF TEMPERATURE OF A BARRACK WITH THIS ROOF, AND WITH ONE OF SMALL TILES OVER SIX INCHES OF GRASS

European, Infantry,	Barrack roof, small tiles over six inches grass, 24 feet high to tie-rod
	Barrack roof, Colonel Goodwyn's tiles, 24 feet to tie-rod
	Quarter-Guard, Colonel Goodwyn's tiles 17 feet to tie-rod
Artillery,	Canteen, Colonel Goodwyn's 20 feet to tie-rod

The experiment was made from the 12th July to the 12th October, 1853, khus-khus tatees having been in use until the 30th June, during which period it was not considered advisable to make the experiment The thermometers were all similarly placed, six feet above the floor and read off at mid-day, when the gun fired, the thermometers where first compared, and the readings reduced accordingly It appeared from this experiment that there is really no difference of temperature between the tiled and grass, and tiled roof with 24 feet elevation, and that it is not advisable to have Colonel Goodwyn's tiled roof less than twenty feet above the floor, if to be occupied by Europeans, and that a ceiling cloth should be used to cut off the heat of the roof in small buildings, as Staff-Sergeants' bungalows In all buildings that close, there should be ridge ventilators, and in those occupied by Europeans, there should, I think, be more than are at present in use, with six inches clear opening on each side of the ridge pole

CONCLUDING REMARKS

The earliest of Colonel Goodwyn's tiled roof constructed here has been finished nearly two years, and has never leaked or needed repairs,

and apparently will not require anything beyond pointing and re-placing of broken tiles for years

It is probable that with the heavy rains of Bengal, the roof might become saturated throughout, and a few drops percolate through, yet this would altogether be avoided by glazing the tiles, but if well constructed (and it requires the very best materials and careful labor) I do not think a better roof could be contrived for Upper India, being free from breakage, promising great durability, and with some trouble made anywhere

It appears to me essential that this roof should terminate at the eave with a masonry cornice, and not with boards, and tiles 12 × 18 × 2 inches, would I think be better than 12 inches square

The pan and round tiles if made three-quarter inch thick, when burnt, and nailed on to battens, make an excellent roof for ordinary purposes of godowns, gun-sheds, stables, &c, &c

J N SHARP

No. XIV

ON THE STABILITY OF ARCHES, WITH REFERENCE TO THEIR FORM.

BY ARCHDEACON J. H. PRATT.

To the Editor.

SIR,—Having been asked to give an opinion, on theoretical grounds, regarding the stability of a bridge about to be erected in this country, I calculated some formulæ, which, as I have not seen the subject treated in this way anywhere else, I think may be of use to some of your readers.

The stability of an arch may be endangered from three causes—1st, The pressure at certain points may be such as to crush the materials; 2nd, The friction of the voussoirs against one another may not, in one or more parts, be sufficient to prevent their sliding one past another, under great pressure; 3rd, The form of the arch may be such that when a load comes upon it the arch may become broken, by the voussoirs opening in the intrados and extrados.

It is this last case which I consider in the present paper.

In some cases Engineers appear to consider that an arch will be stable if it is capable of bearing the greatest load which is ever likely to come upon it, *placed simultaneously on every part of the road-way*, and calculations are gone into, based sometimes upon the law of the inverted catenary, to ascertain how deep the voussoirs ought to be and how the materials above the arch ought to be arranged, so as to preserve all in equilibrium, when a load is spread over the whole road-way uniformly

This might be very well if the arch were merely an architectural structure, to bear always one and the same weight and no other! But if an arch is to do duty in a bridge, it is to be subject to unequal pressure upon its several parts as loads pass over it, and an arch which might stand for ever in the former case, might soon fall to ruin in the latter. In the following calculation, therefore, I suppose a load placed over the arch *first* on one side, and *secondly* over the centre, and the course I adopt is this, I imagine the arch to be broken into portions and slightly forced out of its position and held so, and then left to itself. If the parts collapse, I consider that the arch, as regards its form, is stable; if the parts do not collapse when left to themselves the arch is unstable and dangerous. With this explanation the following diagram speaks for itself.

Fig 1

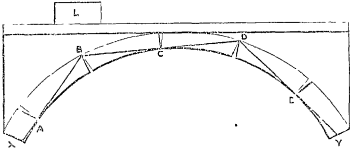
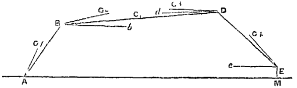


Fig 2



$$\angle\,BAM = \alpha_1,\ \angle\,CBb = \alpha_2,\ \angle\,CDd = \alpha_3,\ \angle\,DEe = \alpha_4,$$
$$\angle\,G_1AB = \beta_1,\ \angle\,G_2BC = \beta_2,\ \angle\,G_3DC = \beta_3,\ \angle\,G_4Ee = \beta_4,$$
$$AB = a_1,\ BC = a_2,\ CD = a_3,\ DE = a_4,\ AM = m,\ ME = n,$$
$$AG_1 = b_1,\ BG_2 = b_2,\ DG_3 = b_3,\ EG_4 = b_4$$

h_1, H_1, h_2, H_2, h_3, H_3, h_4, H_4, are the lengths of the projections of AG_1, AB, BG_2, BC, DG_3, DC, EG_4, ED upon the horizontal line AM

I Suppose a load, L (*Fig* 1) to be placed on the bridge over the arch, and not in the centre B is the point of the extrados under the middle of the load Draw BAX, BCD, DEY tangents to the intrados Imagine the arch at the points A, B, C, D, E, to be divided into four parts, and to be forcibly held in the position shown in the diagram, in which the arch is slightly open at joints through those points If the equilibrium of the arch is stable, the parts will fall back into their places when left to themselves, if unstable, the arch will fall

The manner in which I shall apply this principle is as follows —I shall find the algebraical expression for the height of the centre of gravity of the four parts into which the arch is divided above a fixed horizontal line and shall ascertain whether a very slight change in the positions of those parts will *raise* or *depress* their centre of gravity In the first case the arch is stable, because the centre of gravity (which will always descend) will descend and bring the parts together again, in the second case, the arch is unstable, because the centre of gravity will descend and separate the parts more than they were and the whole will fall The following is the calculation —

Let W_1, W_2, W_3 W_4, be the weights of these four portions of the arch, including the total load each carries (not omitting L) G_1, G_2, G_3, G_4, (in *Fig* 2), the centres where these weights may be supposed to be collected Let V be the height of the centre of gravity of these four weights above the horizontal AM Then

$$(W_1 + W_2 + W_3 + W_4)\,V = W_1\,b_1 \sin(\alpha_1 + \beta_1)$$
$$+ W_2\big(a_1 \sin\alpha_1 + b_2 \sin(\alpha_2 + \beta_2)\big) + W_3\big(n + a_4 \sin\alpha_4 + b_3 \sin(\beta_3 - \alpha_3)\big)$$
$$+ W_4\,(n + b_4 \sin\alpha_4)$$

Also the angles are connected by the following relations (*N B* $\alpha_3 = \alpha_2$, because BC and CD are in the same straight line but I shall at first reason on the more general supposition that they are not necessarily so),

$$a_1 \cos\alpha_1 + a_2 \cos\alpha_2 + a_3 \cos\alpha_3 + a_4 \cos\alpha_4 = m,$$
$$a_1 \sin\alpha_1 + a_2 \sin\alpha_2 + a_3 \sin\alpha_3 - a_4 \sin\alpha_4 = n$$

Differentiating these with respect to the angles, which alter when the arch is slightly moved out of its position

$$a_1 \sin\alpha_1\,\delta\alpha_1 + a_2 \sin\alpha_2\,\delta\alpha_2 + a_3 \sin\alpha_3\,\delta\alpha_3 + a_4 \sin\alpha_4\,\delta\alpha_4 = 0,$$
$$a_1 \cos\alpha_1\,\delta\alpha_1 + a_2 \cos\alpha_2\,\delta\alpha_2 + a_3 \cos\alpha_3\,\delta\alpha_3 - a_4 \cos\alpha_4\,\delta\alpha_4 = 0$$

I have kept α_2 and α_3 general, that I might obtain these equations by differentiation. Now consider them equal, and obtain $\delta\alpha_3$ and $\delta\alpha_4$ in

terms of δa_1 and δa_2 by these equations Multiply the first by cos a_2 or cos a_3, and the second by sin a_2 or sin a_3, and subtract,

$$a_1 \sin (a_1 - a_2)\, \delta a_1 + a_4 \sin (a_3 + a_4)\, \delta a_4 = 0,$$

$$\therefore \delta a_4 = -\frac{a_1}{a_4} \frac{\sin (a_1 - a_2)}{\sin (a_3 + a_4)} \delta a_1$$

Again, multiply the two equations by cos a_4, sin a_4, and add, then

$$a_1 \sin (a_1 + a_4)\, \delta a_1 + (a_2\, \delta a_2 + a_3\, \delta a_3) \sin (a_3 + a_4) = 0,$$

$$\delta a_3 = -\frac{a_2}{a_3} \delta a_2 - \frac{a_1}{a_3} \frac{\sin (a_1 + a_4)}{\sin (a_3 + a_4)} \delta a_1$$

Now differentiate the expression for V, observing that β_1 are constant, and substitute the values of δa_4 and δa_3, also substitute h_1 H_1 which have been explained above, and are $b_1 \cos (a_1 + \beta_1 = h_1)\, a_1 \cos a_1 = H_1$,

$$\therefore (W_1 + W_2 + W_3 + W_4)\, \delta V$$

$$= W_1 h_1 \delta a_1 + W_2 (H_1 \delta a_1 + h_2 \delta a_2) + W_3 (H_4 \delta a_4 - h_3 \delta a_3) + W_4 h_4 \delta a_4$$

$$= \delta a_1 \left\{ W_1 h_1 + W_2 H_1 - (W_4 h_4 + W_3 H_4) \frac{a_1}{a_4} \frac{\sin (a_1 - a_2)}{\sin (a_3 + a_4)} \right.$$

$$\left. + W_3 h_3 \frac{a_1}{a_3} \frac{\sin (a_1 + a_4)}{\sin (a_3 + a_4)} \right\} + \delta a_2 \left\{ W_2 h_2 + W_3 h_3 \frac{a_2}{a_3} \right\}$$

Suppose that AB and ED are produced to meet in the point F (not drawn in the diagram), and that the angles of the triangle FBD are called F, B, D Then the above formula becomes

$$(W_1 + W_2 + W_3 + W_4)\, \delta V$$

$$= \delta a_1 \left\{ W_1 h_1 + W_2 H_1 - (W_4 h_4 + W_3 H_4) \frac{a_1}{a_4} \frac{\sin B}{\sin D} + W_3 h_3 \frac{a_1}{a_3} \frac{\sin F}{\sin D} \right\}$$

$$+ \delta a_2 \left\{ W_2 h_2 + W_3 h_3 \frac{a_2}{a_3} \right\}$$

δa_1 and δa_2 are independent and arbitrary variations of a_1 and a_2 δa_1 cannot be positive and δa_2 cannot be negative, owing to the structure of the arch and the way in which the openings take place Take the most unfavorable case, where $\delta a_2 = 0$, that is, suppose the point C slides slightly to the right, along CD Then δV, or the variation of height of the centre of gravity of the four weights (measured upwards), will be positive or negative according as

$$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1} + W_3 \frac{h_3}{a_3} \frac{\sin F}{\sin D} \text{ is } < \text{ or } > \left(W_4 \frac{h_4}{a_4} + W_3 \frac{H_4}{a_4} \right) \frac{\sin B}{\sin D}$$

In the first case the arch will be stable, because the slight displacement raises the centre of gravity, and as this will fall, the openings will close up again when the arch is left to itself. In the latter case the centre of gravity descends, owing to the displacement of the parts

of the arch, and will go on descending when the arch is left to itself, and therefore the arch will fall

The application of these principles to a particular case is as follows — When any design of an arch is determined upon, suppose different portions of the load L, and find all the quantities involved in the above formula by construction and measurement by a scale, and the character of the proposed arch for stability will be at once determined

Example —Suppose W_1, W_2, W_3, W_4 are as 10, 6, 5, 9, *independently of* L, and $\sin B = \sin 55° = 0·819$, $\sin D = \sin 45° = 0·707$, $\sin F = \sin 80° = 0·985$ also suppose that

$$\frac{h_1}{a_1} = \frac{1}{6}, \frac{H_1}{a_1} = \frac{1}{2}, \frac{h_3}{a_3} = \frac{3}{7}, \frac{h_4}{a_4} = \frac{2}{5}, \frac{H_4}{a_4} = \frac{9}{11}$$

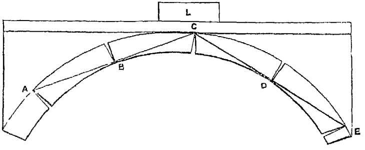
Putting these in the above formula of comparison, the values of the two sides will come out 7·65 and 7·89 The first is less than the second, and therefore the arch would be in itself stable Now introduce L, and suppose the centre of gravity to be over B, and half added to W_1 and half to W_2 Then the two sides of the comparison will become,

$$7·65 + 0·75 \text{ L and } 7·89,$$

and therefore the arch will be at its limit between stability and instability when these are just equal to each other, that is, when L = 0·32, or about $\frac{1}{0\cdot32}$th part of the weight of the whole bridge Practical men must decide whether this would be safe

II Suppose, in the next place, that the load L is near the crown of the arch, and that the arch is forcibly held in the position marked in *Fig* 3

Fig 3



By reasoning precisely as before, and observing that in this case $a_2 = a_1$ and $a_3 = a_4$, we obtain—

$$a_1 \cos \alpha_1 + a_2 \cos \alpha_2 + a_3 \cos \alpha_3 + a_4 \cos \alpha_4 = \text{constant},$$

$$a_1 \sin \alpha_1 + a_2 \sin \alpha_2 - a_3 \sin \alpha_3 - a_4 \sin \alpha_4 = \text{constant},$$

$$\therefore a_1 \sin \alpha_1 \, \delta\alpha_1 + a_2 \sin \alpha_2 \, \delta\alpha_2 + a_3 \sin \alpha_3 \, \delta\alpha_3 + a_4 \sin \alpha_4 \, \delta\alpha_4 = 0,$$

$$a_1 \cos \alpha_1 \, \delta\alpha_1 + a_2 \cos \alpha_2 \, \delta\alpha_2 - a_3 \cos \alpha_3 \, \delta\alpha_3 - a_4 \cos \alpha_4 \, \delta\alpha_4 = 0,$$

which, since $\alpha_2 = \alpha_1$, $\alpha_3 = \alpha_4$, give

$$a_1 \, \delta\alpha_1 + a_2 \, \delta\alpha_2 = 0, \quad a_3 \, \delta\alpha_3 + a_4 \, \delta\alpha_4 = 0$$

Also—

$$(W_1 + W_2 + W_3 + W_4)\, V$$

$$= W_1 b_1 \sin(\alpha_1 + \beta_1) + W_2 \left(a_1 \sin \alpha_1 + b_2 \sin(\alpha_2 + \beta_2)\right)$$

$$+ W_3 \left(a_4 \sin \alpha_4 + b_3 \sin(\alpha_3 + \beta_3)\right) + W_4 b_4 \sin(\alpha_4 + \beta_4) + \text{constant};$$

$$\therefore (W_1 + W_2 + W_3 + W_4)\, \delta V$$

$$= \delta\alpha_1 \left(W_1 h_1 + W_2 H_1 - W_2 h_2 \frac{a_1}{a_2}\right) + \delta\alpha_4 \left(W_3 H_4 - W_3 h_3 \frac{a_4}{a_3} + W_4 h_4\right)$$

$\delta\alpha_1$ and $\delta\alpha_4$ must both be positive. Hence the equilibrium will be stable if

$$W_1 \frac{h_1}{a_1} + W_2 \frac{H_1}{a_1} \text{ be not } < W_2 \frac{h_2}{a_2}, \text{ and } W_3 \frac{H_4}{a_4} + W_4 \frac{h_4}{a_4} \text{ not } < W_3 \frac{h_3}{a_3}$$

If the numerical values of the example already given are substituted the result shows, that the arch would be stable in this position of the load, however great the load is.

If the two sides of the formula of comparison are, in any example of an arch, very nearly equal, this would show that the parts are very nearly balanced, the line of pressure, when the arch is not divided, would in this case pass very near the intrados (C in *Fig* 1, B and D in *Fig* 3). The materials at those points would be under a great strain as a heavy load passed over, and portions might be chipped off. In this way an arch, although its data might (though only just) satisfy the conditions of stability, would really be unsafe. There should be a decided difference between the numerical value of the two sides of the formula of comparison to ensure stability.

J H P

No XV

PUBLIC WORKS IN MYSORE

Report by MAJOR R H SANKEY, R E, *Assistant to the Chief Engineer, to the Officiating Chief Engineer in Mysore, of two tours of inspection made by him in that Province*

Bangalore, 30th May, 1863

HAVING been directed by the Government of India to furnish a digest of the report on my inspection tour undertaken in November, and further being requested by the Commissioner to add some particulars connected with my examination of works in another portion of the Province during last month, I have the honor to offer the following observations, and at the outset beg to state briefly the extent and objects of the journeys in question

On my November tour, while proceeding along the Mysore road, I inspected chiefly the Anicut now constructing across the Shumsha river at Muddoor, the site of the proposed large Soolakeriay tank, and also the position for an aqueduct over the Lokani river near Seringapatam Continuing my route through Yelwall, I turned north and examined the proposed new line of road leading direct from Mysore to Hassan, with the sites for the bridges, which may eventually span the Cauvery and Hemavutty rivers at Yedtora and Nursipoor

Proceeding thence to Arculgode and Coodlipett, I was enabled to see nearly the whole of the road now under construction between that place and Mercara in Coorg, and subsequently the Munzerabad ghaut, the site of the proposed bridge over the Hemavutty at Saklaspoor, the road leading along the western ghauts to Moodgheriy, the Boond ghaut (now under construction), the road through Chickmugloor to Santawaea, and the top of the Bababooden mountains, the proposed new

ghaut leading down from Santawara to Lingadhully, and the new road from Terrikerray to Adjumpore

From the latter place, striking across the valley of the Huggary by Hossdroog, I reached the Mauri Cunavai, and subsequently proceeding to Herrioor, returned by the main road to Bangalore The whole of this route, which can be easily traced on the Map, is about 600 miles in length, and occupied the whole of the month of November

During the last week of April, I inspected the new Railway feeders to the east of Bangalore, and then proceeding along the new Cuddapah road, as far as the frontier at Ralpand, returned to Chintomonipett, and rode over the proposed line from that place *vid* Sandly to Bagapully, near the Madras frontier, on the Ghooty road From this point striking across country, I passed through the mountainous tract at Goodybundah and thence to Goreebednore, visiting *en route* the fine tank at Wottadahoshully

From Goreebednore I returned south to Dadaballapoor, examining the proposed line of road between these two places, and subsequently, after inspecting two ghauts north of Nundidroog, and some short roads now under construction about that place, returned to Bangalore

Taken together these tours extended over 900 miles, and enabled me to see most of the important works either under execution or proposed Of these, I shall now endeavour to explain concisely the most important features, adding some observations of a general nature connected with the working of the department, &c

The Muddoor Dam —The Muddoor dam, which was the first work inspected by me, and the most important irrigation work hitherto undertaken in the Province, lies eight miles north-west of the town of the same name, half way between Bangalore and Mysore The present work was undertaken with a view of replacing the old native Anicut across the Shumsha river, which from defective construction (core, *loose stone and earth*, facing, *brick*, top, long stones packed dry on end, foundation, *rock*, length 300 yards, average height, 13 feet, breadth, 40 to 60 feet) leaked a great deal, gave perpetual trouble, and was liable to be carried away by the first high flood *Fig* 1

The new Anicut, *Fig* 2, is being constructed immediately in rear of the old one, the material of which is being turned to account. It is only ten feet broad at the top, which is formed of cut stone laid on

brick in chunam, facing, brick in chunam, core, boulders and small stone grouted in, backing, cut stone in steps

The channel which leads off from a head or regulating sluice at the west flank of the work is eleven miles long, passes through two tanks above three others, and from the quantity of water which will now be available a new tank is to be constructed, and the tail of the channel led to the large Casbah tank at Muddoor From the great value of land thus brought under irrigation, the returns on the outlay are calculated at 16 per cent, and will probably exceed this when the works are completed and the whole of the water utilised

When inspected by me, about 150 feet of the dam had been carried to very nearly the full height, and although thus exposed with one end, *en l'air*, it had successfully withstood the rush of some severe floods which had passed over it during the monsoon Nothing could be sounder or more satisfactory than this portion of the work

This work, the idea of which originated with Captain Johnson, the Executive Engineer, will doubtless, when completed, prove a great success, and this will be the more satisfactory as the strength of the department has been severely tried by its execution When commenced there appeared no probability of obtaining properly qualified superintendence, and the country afforded no labor, carts or cattle, everything almost had to be imported Floods came down the river, material was destroyed by rain, cholera broke out among the work-people, and the superintendence has been very inefficient, yet in spite of everything, the work has advanced, and though again delayed by unseasonable and almost unprecedented rain, will, I hope, be sufficiently advanced this season to make good our pledge of bringing nearly all the tract between the channel and the river under irrigation

Soolakerray Tank—A few miles past Muddoor, the new Seevasamoodrum road takes off in a southerly direction, and the work of formation is progressing satisfactorily, it is not, however, bridged as yet. After proceeding some distance along this road and turning off to the village of Sadallahully (shown in the Trigonometrical Survey), a view is obtained of the rich valley, which will probably at no great distance of time be brought under the effects of irrigation from the proposed large Soolakerray tank, the formation of which has long been contemplated by the Mysore Engineers

PUBLIC WORKS IN MYSORE

Fig 1

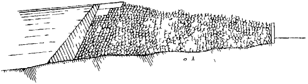


Fig 2

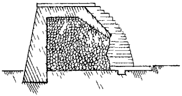


Fig 3

Fig 5

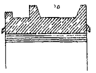
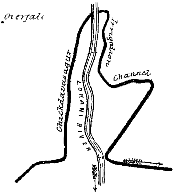
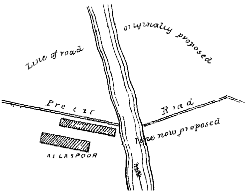


Fig 4



N B Dotted lines show the alternative sites for aqueducts

Fig 6



There is an old native bund now existing across the valley 11 or 1,200 yards long, and varying in height from twenty to forty feet Gaps were left in the bund for the sluices, the whole front faced by magnificent blocks of stone, and the only remaining work was the construction of sluice and waste weirs, with the filling in of the centre part of bund, through which the river now flows in a bed some seventy feet below the crest of the bund Possibly, the difficulty of filling in this great central gap intimidated the original native projectors of the work, for it was evidently never finished, or the tank brought into action

The fall of the river is no less than eleven feet per mile, and the flood section 200 feet wide by fifteen feet in depth, and all are agreed that the supply of water would be most abundant Captain Johnson had a survey taken and levels run for the high level channels, and had framed an estimate, amounting to two lakhs, for raising the present bund twelve feet, and otherwise completing the work The whole project is certainly well worthy of consideration, but being under the impression that in the absence of reliable data regarding the supply of water, it would be undesirable to propose so large an extension of the work, I recommended that after further investigation an estimate should be framed, which should provide for little more than the completion of the original native work, as we would thus, it appeared to me, insure large profits at a minimum cost

This suggestion is now being acted upon, and there is every reason to believe that a detailed estimate will be ready for entry in the next budget

The Lokani Aqueduct —After proceeding about eight miles beyond Mundiem, on the Mysore road, and turning off to the military station known as the French Rocks (Erode on the Map), the Lokani river is met about two miles from the station, and just at this point is crossed by the great Chickdavasagur irrigation channel, which, taken off from an Anicut several miles up the Cauvery river, here diverges nearly five miles from the stream and converts the whole of the intervening ground into a sheet of wet cultivation—the finest in the Province

The channel has a total length of 72 miles, and produces a yearly revenue of Rs 69,000, its maintenance in a thorough state of efficiency is therefore of the greatest importance to the State, yet, considering that the canal by reason of its length, crosses a great amount of drainage from

the upper lands, this is necessarily a matter of considerable difficulty, and especially is this the case at the point above-mentioned

The channel is carried across the bed of the Lokani by means of an old native weir, *Figs* 3 and 4, (200 feet long, 17 or 18 feet high, composed of large blocks of stone packed on end at the surface, and abutting against rock at foot,) and the river floods find vent by rushing over this into the natural channel below At such times, however, so much silt is brought down into the irrigation canal on either side, that frequently at the most critical period for the cultivation, water is prevented passed down for ten days or a fortnight After violent floods, moreover, the weir itself often needs much repair It is, therefore, most desirable, on all accounts, that the difficulties at this point should be overcome, by doing away with the weir altogether, and carrying the canal over the Lokani at some site lower down by means of an aqueduct

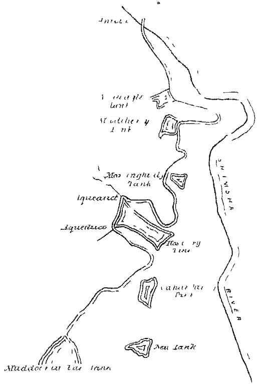
I was enabled to select three alternative sites for the required work with Captain Johnson, all good in their way Each has its peculiar features, which it is unnecessary to detail here, and as the adoption of one or other must depend mainly on the amount of estimate now under preparation, it will suffice to say that the work will probably be entered in the next budget

There is the most distressing waste of water all along the many fine channels led off from the Cauvery and Hemavutty rivers, and it will need years of the most persevering efforts to bring the matter at all into a satisfactory state A newly constituted establishment has been placed lately under the revenue authorities for general purposes of conservation, and with their aid and the steady correction of such defective points as that above-mentioned, much will be effected in time Valuable as these channels are now, they would become infinitely more so under proper regulation, as not only could their length be greatly increased and much more land brought under irrigation, but by securing a constant supply of water throughout the year, the area of such highly remunerative crops, as sugar-cane, mulberry, &c , could be vastly increased The subject is of the highest importance, but as it is also an intricate one, I can do no more than allude to it here

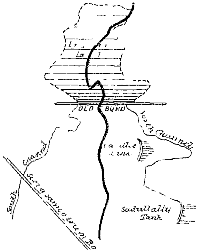
I may now advert to the condition of the communications in this part of the country Although only little more than half a century has passed since Buchanan reported, that the traffic was confined to pack bullocks

PUBLIC WORKS IN MYSORE

MUDDOOR TANK



SOOLAKERRAY TANK



and donkeys, a net work of imperial roads, provincial and district, now covers the province, and this is being further completed by Talook roads, either under execution or projected. As the Map shows the present position of matters, much better than could be described, I shall confine myself to observations regarding one or two missing links in the chain of communications, investigations connected with which formed one object of my tour.

Mysore and Hassan Road.—The chief of these is between Mysore and Hassan, the latter place (or rather perhaps Nursipoor) being one of the great trade centres on the east of the ghauts. Chickmuggloor in Nuggur being the northernmost. In proceeding now from Mysore to Hassan the road after passing the Wellesley bridge at Seringapatam takes north as far as Chewroypatam, where turning at right angles to the west, Hassan is reached after a circuitous route of sixty-nine miles. It will be observed, moreover, that while thus lengthening the distance very considerably, it leaves the whole of the rich country on the right bank of the Hemavutty altogether cut off from communication with the main arteries of the province. This defect it has long been thought desirable to remedy, and efforts have been made through the means afforded by the plough tax fund, to establish a direct road which shall lead from Mysore through Yedtora and Nursipoor to Hassan.

The first link in the line, viz., from Mysore to Yelwall, has long been a second class road, and a short plough tax or fourth class road is being worked out between Yelwall and Yedtora. After this there occurs a gap to within ten miles of Nursipoor, where again a fourth class road is under execution. A rather indifferent third class communication joins Nursipoor and Hassan. My attention was directed to the establishment of a properly bridged third class road from end to end, and an estimate with this object is now being framed.

The total length of the road will be fifty-nine miles, and a bridge will eventually have to be constructed over the Cauvery at Yedtora and the Hemavutty at Nursipoor, but if proper ferry boats be substituted for the present primitive basket-boats, the expense of bridges need not be immediately incurred.

In addition to these rivers the only one of importance which crosses the proposed road is the Lutchmanteerth, but very opportunely an old and useless aqueduct spans the stream at a very good part for the road,

and this will readily turn into a bridge. It may be mentioned that this aqueduct is in connection with a channel taken off from the Cauvery below Yedtora, and formed part of a gigantic project undertaken by the celebrated Dewan Pooneah, for supplying the town of Mysore with Cauvery water. Alongside, and forming part of the work, is a roadway ten feet wide, so that by simply throwing down the wall separating this from the aqueduct portion, a fine road will be at once formed of thirty feet in clear width. *Fig.* 5.

When in the process of time it may become desirable to bridge the Cauvery and Hemavutty rivers, no difficulty will be experienced, as the banks (each about 400 feet apart) are high and the beds consist throughout of rock. The only precaution required will be with reference to the provision of sufficient waterway for extraordinary floods, one of which I find occurred in 1822, and rose to a considerable height, twenty-two feet at Yedtora, twenty-eight feet at Nursipoor.

The construction of the road in all other respects will prove neither difficult nor expensive, both the soil and gradients being favorable throughout, and the amount of drainage to be provided for small.

Mercara and Coadlipett Road.—The next link of importance which it is desirable to complete is that leading direct from Mercara in Coorg, *viâ* Coadlipett to Munzerabad the great centre for coffee plantation in this part of the province. Between Munzerabad and Coadlipett there has been for some years a bridged road, and for the last two years, work has been in progress on the forty-three miles of road between Mercara and Coadlipett. At the period of my inspection my baggage cart got easily over the eighteen miles between Coadlipett and Somwarpett, and it is expected that the whole amount now remaining to be executed (about five miles) should be worked through in a year. Though carts will thus soon be enabled in favorable weather to proceed with produce from end to end, it must not, however, be understood that the road will be nearly complete, as the communication so far is sustained by means of log bridges over all nullahs, which must give place to others of a permanent description; and further, as the road itself will have to be widened, the surface corrected, and three bridges built, one over the Chorauhully (one span of fifty feet), another over the Mahadapoorhully (two spans of fifty feet), and a third over the Huttee river (three spans of fifty feet).

In this part of Coorg there are several old native tracts leading over

hill and dale to the marts of Soobramany, &c, through Somavarsunttay and Frasepett (Kooshalnuggur of the Map), but as these climb up the steep sides of mountains and through dense forests wholly regardless of gradients, the traffic has hitherto necessarily been confined to pack cattle The road, however, now being constructed, though in a few places rather steep, (i e, having gradients as high as one in twenty), will allow of fully laden carts using it, and it will doubtless be followed in time by many other roads, opening up the most valuable sites for coffee plantations, of which there would appear to be scarcely any limit

The estimate first framed for the work, Rs 20,000, as may be imagined, will prove wholly inadequate A correct survey with full details, &c, will, however, be shortly in the hands of Government, the Assistant Engineer in charge, Mr Stoddard, having now been long engaged upon it Estimates for the three bridges above-mentioned were submitted last year, they were to be timber trusses, masonry being thought too expensive in consequence of the great distance from which lime has to be procured (none is to be found in any portion of the Mysore ghaut) and the difficulty of procuring bricklayers If we could get Messrs Knight and Company, to tender for Iron Lattice bridges in lieu of the proposed timber ones, the result would undoubtedly be much more satisfactory

The Saklaspore Bridge —The next work of importance which I had an opportunity of inspecting, was the proposed bridge over the Hemavutty at Saklaspore, the head of the Munzerabad ghaut The original estimate for this work provided for six timber trussed spans of sixty feet each, amounted to Rs 98,117, but this has been in a measure set aside by a proposal, now before Government, to substitute for it a bridge consisting of three Iron Lattice spans of 120 feet each, and it is hoped the matter will receive favorable consideration

My attention was simply directed to the choice of a proper site for the work, the one originally selected lying some way north of the town, and necessitating long embanked approaches I am quite satisfied that the bridge may most advantageously be placed just below the present ferry, and in the direct line leading through the town of Saklaspore The river at this point is exceedingly straight for half a mile up and down-stream, and there being but little embanking, and no provision required for lateral drainage, from Rs 15 to 17,000 may be saved on the estimate *Fig* 6

The Kempahull Bridge.—Regarding the Kempahull bridge at the foot of the ghaut, and the ghaut road itself, little need now be said, as both will form the subject of special estimate before long. It may however, be observed that the climate at the foot of the ghaut is so unhealthy, that it appears almost hopeless to assign either reliable time or rates for the execution of any work there, and, consequently, with reference to the bridge in question, it would seem to be the wisest policy to have it constructed in the most rapid and efficient manner, *i. e.*, by employing Iron Lattice trusses. At present there is an old timber structure which serves to keep up the communication, enabling the coffee planters, whose estates spread far and wide over the head of the ghaut, to send their produce by cart to Bangalore, instead of by pack bullocks, which latter method entails the greatest inconvenience with reference to sorting the different classes of berries at the port for the European market.

The Boond Ghaut.—The next work worthy of consideration is the so called Boond (Coffee) ghaut, situated twenty-four miles north of Munzerabad. It has been in hand for seven years, and last year an estimate amounting to Rs. 34,682 was sanctioned for opening it out for cart traffic. When completed, it should allow the coffee of the estates lying about the Bababooden hills (the oldest plantations in South India) being conveyed direct to Bangalore. Much of the Munzerabad coffee may also eventually follow the same route. It is quite possible that the designation assigned to this ghaut has lost somewhat of its distinctive significance, since the rise of Munzerabad and Coorg as centres of coffee production, but in addition to the valuable estates about the Bababoodens, there is an almost boundless tract of country lying northward between the Boond and Agoombee ghauts, which, when opened up by roads, will probably restore the preponderance to this line, and make it the most frequented on the Western Ghauts.

The work is so important in itself, and of such a peculiar character, that I make no excuse for giving some further details connected with it, although I understand my full report has already been submitted to Government.

Kotegar, which is the recognized head of the ghaut, is little more than an open piece of ground favorably placed for a bazar and bullock encampment. A small village now exists there, and the place is to a certain ex-

tent sheltered from the monsoon by the hills which crown the summit of the ghaut, and cluster round the pass through which the road is carried

Leaving Kotegar and passing round a thickly wooded knoll to the right, the side cutting being very heavy at this portion, the road descends with an easy gradient to the so-called Custom House bridge, at which point the central stream of the valley is crossed

A little in advance of this point the whole valley bursts on the view in a magnificent panorama On either side the mountains, which are for the most part covered by grass, with deep thickly wooded glens running nearly to the summits, appear to descend with great abruptness and at once impress one with the boldness of the work Further, as the Hooleekullbettah (Tiger Mountain) rises directly in front and appears to close completely the valley to the west, it would seem at first that there was no outlet to the basin

The thin line of ghaut road which is seen climbing along the great mountain spurs to the right, and gradually descending towards the Hooleekullbettah, shows, however, that there is an exit in that direction, and after traversing the road for eight and a half miles (the total length of the Mysore portion) from the head, the spectator finds himself directly fronting this lofty pyramidal mountain with a wide valley opening seawards on his right hand, and affording an almost endless prospect of the Canara country at his feet

The Mysore portion of ghaut, which is generally twelve to fifteen feet wide, falls very gently to a point about five and a half miles from Kotegar Here the line ascends for half a mile, it having been considered inadvisable to attempt to carry it with the same gradient across a rocky cliff nearly 500 feet in height, which here bars the path As I forward a sketch of this point, showing the road passing over the top of the shoulder, it will be at once seen how this formidable obstacle rules the gradient of the ghaut so far, and that there existed good reason for the adoption of the present line

The remaining two and a half miles of road from this point (known as the top of the counterslope) descends with an easy gradient to the Madras frontier, where there is a short zig-zag joining the two traces Some very formidable obstacles had to be encountered in this portion, the chief of which was the Codakull, (Umbrella Rock,) which formed part of a precipice of sheet rock some 350 or 400 feet in depth, and for a long

time effectually baffled all efforts to cross. A happily lodged charge of powder, however, produced a slight displacement, and the whole obtruding mass some 100 feet long by 15 feet thick becoming detached, rushed into the valley below, and allowed of a sufficiently wide road being established across the ledge. It is unnecessary to dwell upon other impediments of a similar nature as all real difficulty has now vanished, and the completion of the work is only a question of time.

The Madras portion of the ghaut commences near the head of the second valley, which it reaches by being carried along a saddle connecting the first with the Hooleekullbettah, along the northern slopes of which the road is taken, and descends by a series of zig-zags to the foot at the village of Charmondy. Though steeper than the Mysore portion it is wider, and therefore more advanced for cart traffic, but as some rivers in the low country still require to be bridged, the opening of the through line to the coast cannot be looked for immediately. With vigorous efforts I have no doubt that produce could be sent down the ghaut by carts in two years.

Even now in the unfinished state of the road, the amount of traffic carried on during the dry season is very considerable. (In the monsoon, the difficulties occasioned by the great rain-fall on this portion of the ghauts, coupled with the dread of meeting wild elephants, which are frequently to be met with in herds at this season, stop all communication.) Some days, I am given to understand, the number of pack cattle may be counted by thousands, and there can be no doubt, when complete, the road will become the most frequented on the Western Ghauts, the gradients being easier than on any other, and the communication with the port of Mangalore more direct. This result, too, will appear the more satisfactory if it be borne in mind that the inhabitants of this part of the country were never thoroughly subjugated by any native ruler, and that it is only quite of late years that they have ceased to form an *imperium in imperio*.

Of the approaches to the Boond ghaut a few words will suffice. The road leading from Munzerabad to Moodgherry, twenty-one miles in length, passes many valuable coffee estates. At present it is but an unbridged fair-weather road, and will therefore need improvement.

From Kotegar to Moodgherry, and thence to Wustara, Chickmuggloor, Santawarra, and the Bababooden hills, the road is an indifferently

bridged line with at one point an almost impracticable ghaut (the Bussawan Cunawai) which must be retraced. A special estimate for raising the whole of this, the main feeder to the Boond ghaut, to the standard of a third class road is now under preparation, and should appear in the next budget.

An estimate for Rs 32,941 stands in the current year's (1863-64) budget, for constructing a road from Chickmuggloor to Cudnoor *viâ* Sacrapatam and a further amount will be entered next year for making a new ghaut to lead from Santawara to Langadhully. These, with other matters connected with the communications in this portion of the country, were dwelt upon in my detailed report, but as they are not of any special interest they need not be further adverted to here.

As my inspection of the Huggary valley, and the site for the proposed Marri Cunawai tank, near Herrioor, forms the subject of a special report and estimate now being submitted to Government, I shall not advert to the matter at present; the state of the communications in this part of the province may, however, be remarked on concisely.

The wide area between the Cuddoor, Shemoogah, and Herrioor Chittledroog roads, is as yet untraversed by a single road from east to west. Although much of this part of the country, especially the valley of the Huggary, is extremely barren, yet such is not the case throughout. About Chennagherry and other parts there is abundance of black cotton soil, which, from the efforts now being made, will probably prove an abundant source of wealth; there is, therefore, no reason why this part of the province should be left destitute of roads, the more so as it forms a distinct obstacle to communication between the east and western portion of the lately constituted Nuggur division. The Chittledroog district is now practically cut off from Shemoogah, which is the divisional head-quarter.

To remedy this, a road is now under execution from Chittledroog to Doomee and thence to Benkipoor, where there is a fine bridge over the Budra. This road should be formed and bridged within two and half or three years. A short line is also well advanced between Terrikerray and Adjumpore, and I satisfied myself that this could be pushed on through Hossdroog to Herrioor at very little cost, the soil being very favorable and the drainage trifling. A plough tax road is also proposed from Hoolyaur through Hossdroog, Holalkara to Anagode, on the Chit-

tledroog Hurryhur road. When these shall have been carried out the country may be considered as fairly opened.

The next point of importance refers to the supply of labor for our works along the ghauts and especially in the Nuggur district. The natives of this part of the country are so independent (though it will scarcely be credited, several coolies who carried my baggage refused all remuneration, and this I understand is no uncommon occurrence) that the planters as well as our department have to look exclusively to the Lumbances, who, as a class, are as much noted for their laziness as their filth.

Natives from other parts of Mysore soon sicken in the Mulnad (the local name for the country lying under the ghauts to the east) the climate of which they dread. One company of Kalihauts (Mysore Labor Corps) which was sent for work on the Augoombee road soon deserted in a body, and on presenting themselves at Bangalore scarcely a man was able to stand from the effects of fever. The only place from which labor could be drawn to any extent was Canara, but now, since the large works at Shedasegur, &c., have been started, this source has completely failed; not a man is to be procured.

One most fruitful source of difficulty with reference to labor, is the competition arising from the extension of coffee plantations. It frequently occurs that no sooner has one of our subordinates by great labor collected a sufficient body of coolies, than a planter's agent steps in and carries off the whole under heavy advances. So common is this occurrence that it is believed to be systematic. An advance in ready money has thus been made to a single influential cooly of 60 rupees, the rest of the gang getting smaller sums. While, however, it may be satisfactory to know that some of the planters have politely acknowledged the services the subordinates thus render, the difficulties with which our department are left to struggle are most disheartening.

In justice to the planters it must be admitted that they are at times put to grievous stress for want of labor, and when this occurs at a critical time for the crop they have no choice but to get labor at any price. In Munzerabad only a very few years ago, coolies could be got for Rs 2-8. They are now 5 and 6 rupees, and ere long will probably be 7 rupees per mensem. In Nuggur the rate has not gone as yet much higher than 4 rupees, but it is rapidly rising.

In the concluding portion of Lieutenant-Colonel Kennedy's Report

on the works in north Canara, he draws attention to the grave difficulties attending the supply of labor in that part of the country; when, therefore, I mention that to north Canara, Captain Palmer had till lately to look for much of his labor for the works in the Mulnaad, and that even that source is now cut off, the importance of the question as concerns this department will be sufficiently apparent. Spite of every effort works only creep into existence in Nuggur. No contractors can be obtained. Every subordinate either loses his health there and has to be sent away, or, still worse, deserts his post. This is but plain matter of fact, which I think it right to state in justice to the Executive Engineer.

Yet it is absolutely necessary that the valuable coffee land at the back of the Bababoodens and about Coppa, Kig, Namur, &c., should be opened up, and a line of communication established between the Boond ghaut and the country lying north, much of which has probably never been visited by any European, means must therefore be found for grappling with this labor difficulty.

As in some measure likely to effect this object, I would venture to propose that the great bulk of the Kalihaut Corps, now about 852 strong, be sent to the Boond ghaut and Nuggur; that an apothecary with all requisite medicines be attached to each company, and that every man be given good warm clothing; further, that the pay while so engaged be raised to 6 rupees per mensem. In addition to this I would raise more companies in Nuggur itself, and enlist men if possible down the coast. I do not say that this will succeed; much, however, I think can be done by selecting in the first place really able-bodied men, taking care of them and giving high pay.

The Commissioner has lately seen fit to recommend the advisability of making the Executive ranges conterminous with the new civil districts, and there can be no doubt that if this be acceded to, great relief will be given to the Executive Engineer of Nuggur, who is no less overburthened by the difficulties connected with his subordinates, and the supply of labor, than he is by the undue extent of his range. I now beg to pass on to my tour undertaken during the last week of April, the extent of which is given above, and having already made this report too long, I shall endeavor to be as brief as possible.

One main object of this tour was the inspection of the Railway feeders to the east of Bangalore, which have been under execution during the

past year I found them extremely well laid out, and all, with the exception of the line between Colar and the Maimootal (near Coppum) station, nearly completed Even on this line rapid progress was being made There being in no case large streams to cross, the masonry works have been extremely light, still I think the rapid and efficient manner in which they have been executed, shows the great advantage of a proper system of contract, by which they have all been carried out The whole of these roads should be complete by the end of next month, or several months before it is probable the railway will be open to the public

Proceeding round by Tulgaiah and Thadgole, I inspected the 14 terminal miles of the new Cuddapah road, the frontier being about 2½ miles beyond Ralpand Much of the end portion of this road lies through a hilly country covered with scrub jungle, and though there is no bridge here above 30 feet span, a good deal of minor lateral drainage had to be provided for The work has been performed very creditably, and, with the exception of one or two breaks at nullahs in the Madras territory, the line is complete from Bangalore to Cuddapah, and notwithstanding that perhaps no very great amount of through traffic can be expected, it will be a most useful line New bungalows at Tulgaiah and Ralpand had been opened for the use of travellers shortly before my visit

Returning along the same road I was enabled to examine the trace of the proposed line, thirty-two miles in length, leading from Chintomonipett to Bangapillay *viâ* Sandly, and which it is very desirable should be opened soon, both in the interest of the Railway Company and that of the country generally I was enabled to suggest several improvements in the trace, which, with other matters, have been dwelt upon in my detailed report Here it will suffice to say that throughout the line both the soil and gradients are favorable, and setting aside the provision for minor drainage, only three bridges will be required, one over the Pennakernay (three arches of twenty-five feet each) another over the Coosbavutty (one arch of twenty-five or thirty feet), and the third across the Chittravutty river, near Bagapilly, at the junction of the new road with the existing main road from Bangalore to Ghooty This last river will need seven or eight arches of 25 feet

Some wild rocky country is passed through on this road, and a little blasting will be required The survey and estimate originally prepared

under orders of the Executive Engineer, Mr Dobbs, will require but little alteration, and will ere long be forwarded to Government for entry in the next budget

An alternative site had been proposed for crossing the Chittravutty river, but I was led to recommend the one above alluded to as possessing the advantage of placing the Cusbah town of Bagapilly in immediate communication with the main road, and of enabling a plough tax road to be pushed forward, when funds may admit, to the important town of Goomnaickenpollium, which, buried in the rocky mountains to the east, has at present no proper communication with any of the main lines of the country

On referring to the Trigonometrical Survey it will be observed that the Cusbah town of Goreebednore (about twenty-five miles north-west of Nundeedroog) is situated in a valley bounded by a range of hills on the east, stretching northwards from Nundeedroog, on the west by the range containing Daveroy and Mudgherrydroogs, and on the south by Munclydroog, and is thus cut off from communication with other parts of Mysore There exists, it is true, a track through the mountains on the east by which pack cattle and even half laden carts can proceed to Goodybundah and thence to the Bangalore Ghooty road, and again on the south there is a steep ghaut on the south-east of Munclydroog, which gives an exit to some of the produce southwards, but for all the practical purposes of trade the valley is at present excluded from the system of roads in Mysore The natives consider it as belonging to the country below the ghauts

For many reasons it is most desirable to alter this state of matters Not alone is the valley rich and productive, but the Madras (Bellary) authorities are most anxious to have Goreebednore placed in immediate communication with the town of Hindoopoor to the north, to which place they have carried a line in continuation of that leading through Handyanantipoor and Pennacondah

An inspection of the Map will show that if we carry a road from Dodabattapoor through Goreebednore to Hindoopoor, we shall not only open up this hitherto closed valley, but lay the basis for establishing a more direct route than now exists from Bangalore to Ghooty and thence to Hydrabad I inspected the greater portion of this line with Mr Dobbs, and as a trace will be made before long followed by a detailed

estimate, the subject will probably be definitely brought before Government in connection with the next budget

Another obvious line of road is that which would connect Mudgherry with Goreebednore, and thence through Wottadhosshully and Goodybundah to the main Bangalore Ghooty road We have now a line almost finished between Seerah and Mudgherry to the westward, and this proposed road would simply form its continuation, piercing the Gooreebednore valley from east to west, which is very much needed The whole of this line, with the exception of the ghat leading down from Goodybundah to Wottadahoosshully, might be constructed from the plough tax fund, the ghaut which will require careful tracing and working out being left to this department for execution

I may mention that in addition to these lines a plough tax road is project from Goreebednore to Mauchanhully to the south-east and thence to Chickballapore The only difficulty in this communication will be a small ghaut leading through the hills between the two latter places My examination of this ghaut led me to conclude that it must also be carried out by our department, and that before commencing, the line must be accurately surveyed and traced, the ground being extremely difficult and encumbered from end to end by piles of rock

Before leaving this interesting valley I must make a brief allusion to the Wottadahosshully tank, which is, without exception, the finest work of the kind I have seen in the country It is situated at the end of the valley which has its head near Goodybundah, and receives the whole of its drainage, converting the country below, opening to the westward into a wide irrigated plain The approach to the head of this beautiful sheet of water is by the pass in the mountain leading down from Goodybundah, its length, when this tank is full, is perhaps two and a half miles by over half a mile in width Though thus much smaller than many of the tanks in Mysore, it is remarkable for the great height (sixty feet) of the bund, which is 12 or 1,300 feet long, and most picturesquely situated between the two flanking hills at the end of the valley The mountains on all sides are composed of heaped-up masses of granite, and the hill to the south against which the bund abuts on that side, cannot be less than than 1,500 feet high

The bund has a solid stone facing on both its front and rear slopes, and differs very much from all other I have seen, not alone in its height, but

the manner in which the work has been executed, being quite straight and workmanlike throughout The immediate object of my inspection was with reference to the sluice, which was reported out of order and for which an estimate had been framed This I, however, found to be erroneous, and but a trifling amount of work required

I may now conclude this report by mentioning that the only matter of much importance which further required my attention was the so called Nundidroog ghaut, situated north of the hill, and on the provincial road leading through Chickballapoor to Colar It has hitherto been so steep as to prove an effectual bar to through traffic Though a good sum of money will be required to correct its defects, I was enabled to select a line, which on being worked out will give sufficiently easy gradients

R H SANKEY

No XVI

AGRA FORT

Report of a Special Committee, assembled by order of HIS EXCELLENCY THE COMMANDER-IN-CHIEF, *to consider the question of the improvement of Agra Fort*

PRESIDENT

Brigadier St. G D SHOWERS, C B

MEMBERS

Colonel F TURNER, C B, Bengal Artillery, Agent for Gun Carriages
Lieut -Colonel A CUNNINGHAM, Bengal Engineers, Chief Engineer, N W P
Major J H MAXWELL, Bengal Engineers
Capt J D CAMPBELL Bengal Engineers, Superintending Engineer, N W P

Agra, 26th January, 1860

The Committee proceed to take into their consideration the following subjects, as appear to them indicated in the instructions, namely —

1st —Strengthening the fortification as it at present stands

2nd —Formation of outworks as affecting the Jumma Musjid and Tripolya, and the construction of detached posts

3rd —The levelling and clearing of the ground immediately under the walls of the Fort

The Committee having discussed these several subject with plans before them, and having inspected the ground and position, proceed to report as follows

The chief defects of the Fort of Agra are the following —

I —The deficiency of flanking defences

II —The want of a glacis to cover the scarp walls

III.—The great height of all the batteries above the country, and the consequent plunging and defective nature of the fire, which is ineffectual at short ranges.

IV.—The inequality of the ground on all sides, and the dangerous vicinity of the city on the north and west faces, affording cover to an enemy, to within breaching distance of the walls.

The Committee beg to offer the following suggestions, with a view to lessen, or entirely remove, the serious defects above-noted.

I. As to *the deficiency of flanking defences*, we are of opinion that these may be effectually improved by the construction of works in connection with the fort itself, namely—

First.—Earthen bastions outside the corner towers on the river face.

These bastions should be completely isolated from the *fausse braie* by ditches, and be connected with the body of the place by gates. One of these gates, (for the bastion at the north-east corner,) already exists in the northern curtain close to the Shah Boorj tower, and another (for the south-east bastion) exists on the river face of the out-work of the Ummur Singee gate.

These bastions will be so disposed as to afford flanking fire not only to the river face, but also to the north and south fronts, respectively. They will also cover the two weakest points of the fort, which a besieger would be sure to select for attack (and one of which, the south-east tower, was that of Lord Lake's attack). Further, in conjunction with the Water-gate bastion in the centre of the river face, (which will subsequently be noticed in detail,) they will cover with their fire all the ground on the opposite side of the river, which an enemy, contemplating attack on that side could occupy with his batteries, as it is within range from 600 to 1,200 yards.

The proposed north-east bastion also completely covers all approaches to the bridge on both sides of the river, and assists in the flanking defence of the works which are proposed for the Jumna Musjid, within a range of 700 yards.

The new bastion on the south-east provides defence on the line of approach from the direction of the Taj. It also sweeps with its fire, within easy range the two principal ravines on the south side, and covers the approach to the Ummur Singee gateway.

Second.—The conversion of the Water-gate and contiguous bastion

which at present form part of the lower fort on the river side) into a Horn work, cut off from the lower fort, and connected with the body of the place This work will cover the Water-gate, and complete the flanking defences of the river face It will also afford direct fire on the opposite side of the river, it will cover the approach to the bridge from the other side, and co-operate with the flank bastions in the general defence of that front

The Committee are of opinion that the new works, above described in general terms, will suffice for the protection of that part of the fort

Third—For the flanking defences on the land side, the following works seem fully sufficient

On the north covering tower, No 9, should be constructed a Counterguard with flanks, for the purpose of affording flanking fire right and left on the northern face Any more salient work would be objectionable, as advancing the defences towards the city, already too near The Communication with this will be from the *fausse braie* by a bridge across the ditch

At the north-west corner are the Chowk, the Tripolya and the Jumma Musjid, covering the approach to the Delhi gate These buildings must either be removed or occupied If removed, a work of some description to afford flanking fire must be erected on their site The committee, however, think it would be more advantageous to occupy them, by forming them into a permanent out-work, which may be thus effected

The Tripolya, (a small walled enclosure connecting the Chowk with the Jumma Musjid,) with one side of the Chowk, and a portion of the rear wall of the court of the Musjid, must be removed, so as to throw open the interior of the Musjid to the fire of the place The side walls of the Chowk must be prolonged to connect it with the Musjid The standing portion of the rear wall of the court of the Musjid can then be formed into a 2-gun battery, which will flank the proposed counterguard and new bastion on the north The Musjid itself is also capable of being turned into a very formidable battery Five embrasures may be pierced through its western wall, which is 11 feet thick, and very solidly built, and two in each side wall of the mosque itself The side walls of the court-yard will also afford positions for several guns, which on the south side will most effectually sweep the main road to the Delhi gate, as well as much of the low broken ground to the south-west of the Fort

The battery on the west will command a large ravine, which would otherwise afford excellent cover for an enemy's approach

As the piercing of the embrasures through the western wall must be a work of time and labor, it should be begun at once The embrasures themselves may then be closed by thin screen walls, and the building itself thrown open for the use of the Mahomedan population, as convenient access can be had by the two gateways in the side walls These gateways would be closed by sandbags, or other effectual means, on any emergency, and if desired, they can always be closed by the strong iron covered doors at present in them

The Chowk likewise should be made part of the position, by covering its wall with a glacis, leaving the existing road to form the bottom of the ditch, which must also be carried round the Musjid

It is necessary, however, to note that the houses of the city actually touch the north-west corner of the Musjid, and are quite close to the building on other sides, so that to admit of this being retained as an outpost it becomes absolutely requisite to remove a portion of these suburbs, at least to the extent of 200 yards A greater open space, if it could possibly be obtained, would, in the opinion of the Committee, be most desirable, and in accordance with military principles

To obtain flanking fire on the south-west front of the Fort advantage should be taken of the high ground immediately to the west of the Ummur Singee gate, on which to throw up a strong ravelin with flanks, of a permanent character, to be connected with the place by a *caponiere* and covered passage leading into the main ditch

The faces of this work will be swept by the guns of the body of the place, and they will themselves command by their fire the broken ground to the west and south of the Fort Its flanks will cross fire with the batteries of the Jumma Musjid and the new bastion on the south-east

Between the high ground on which it is proposed to made this ravelin and the Fort, runs one of the principal lines of drainage of the city and cantonments, which should be converted into an outer ditch, to be enfiladed by the flanks of the ravelin, which will be rendered more secure by throwing stockades across, on the prolongation of the flanks

II With regard to the second defect—*the exposed state of the scarp wall of the ditch, and general defectiveness of the glacis, and in many parts the total want of one*—it should be stated that at present the counter-

scarp wall is generally at least five feet too low for the efficient protection of the scarp wall of the ditch, and the earthwork of the glacis is not even carried up to the top of the existing wall, so that one-third, and in places, one-half of the wall being visible, a practicable breach might readily be formed by the enemy's batteries from a distance. To obviate this important defect the Committee strongly recommend, that the counterscarp wall should be raised and the glacis properly formed and completed.

III. With reference to the third point—*the defective nature of the fire from the body of the place, owing to the great height of the wall*—the committee beg to recall the recommendation of the committee of Engineer Officers, assembled in 1857, that the walls should be lowered, and to suggest instead, that embrasures should be opened in the curtain walls, on the ground level of the Fort, wherever available, and that the only guns on the high towers be of large calibre, on pivot or traversing platforms, and confined to the most salient towers. These pivoted guns on the towers will assist the flanking fire afforded by the proposed new works, and the demi-casemated batteries of the curtains will, at a much more favorable level, (about 25 feet below the present towers,) protect and cover the ground in their fronts by direct fire. The great height of the walls, the Committee consider a decided advantage, as it precludes the possiblity of escalade, and even when breached, the height will still offer a formidable obstacle, almost an insurmountable one, if the ground behind the breach be properly retrenched.

IV. The Committee desire to remark on *the broken nature of the ground around the Fort*, and on the immediate neighbourhood of buildings, which would afford perfect cover to large bodies of hostile troops in close proximity to the walls, and thus give them the means of establishing their breaching batteries unseen.

On the northern side, the broken ground consists of the *debris* of that part of the city which was thrown down during the outbreak. The Committee recommend that the *debris* on this side should be formed into a second or outer glacis. As this is the weakest side of the fort, on account of the cover afforded by the houses of the city, this advanced glacis will be of considerable advantage, as it will more effectually screen the main wall and so prevent a besieger from establishing his batteries under shelter of the city houses, and force him to advance to the crest of the glacis by the usual process.

On this side there are immediately under the walls two houses left standing, which it will be necessary to remove, also a wall several feet high defining the limit of the fort lands on the city side The rubbish may be thrown into a sunken road close by, which will thus be brought up to the general level

On the south-west side leading down from Boileaugunge to the Delhi gate, there is a sunken road which can only be seen to any extent from the Jumma Musjid The steep side of this road towards the Fort should be sloped off so as to expose the whole line to the view of the place

On the south side, the broken ground is far more intricate and extensive Here also the same general principal should be followed of sloping off the mounds from the fort outwards, so as to present a succession of glacis and expose their whole extent as much as possible to the view of the fort

With regard to the most prominent of these mounds, it may be necessary to occupy some of them by light field works, so as to command as far as possible the uneven ground in their front These works should consist merely of a light parapet and ditch open to the rear, but their exact forms and positions can only be determined when the permanent improvements of the fort are decided upon As the new defences are to be chiefly earthworks, and as very extensive levelling will also be required, it appears to the Committee that it might be more cheaply and expeditiously effected with the aid of some companies of the Corps of Sappers and Miners

In the event of the removal of the Arsenal from Delhi to Agra, and with reference to the increased armament rendered necessary by the enlargement of the works, it appears to the committee that provision should be made for more extensive magazines for powder They therefore take leave to suggest the open square in the middle of the Meena Bazar as the safest and most centrical position for that purpose The place proposed is 114 feet square, already sunk upwards of 20 feet below the level of the surrounding ground, and would afford room for capacious magazines which could only be reached by vertical fire

The *Armament* of the Fort should, in the opinion of the Committee, be as follows.—

On each of the high towers,* (which if not sufficiently strong, should

* Nos 1, 2, 4, 6, 7, 10, 11, 18

be made so,) there should be one 8-inch shell gun, on a pivoted or traversing platform, which will command, to a wide circuit, all the broken ground and houses.

From the great height of these towers, it will be easy to afford cover to the artillerymen when working the guns, and the Committee consider that this armament will be ample for these towers, the fire from which from ordinary guns on account of their great height would be very ineffective.

There should be embrasures pierced through the main walls in as many of the curtains as will admit thereof, and these batteries should be armed with 18 or 24-pounder iron guns, as most available. As the ordnance in these batteries would be partly under cover, and particularly well defiladed, it would be economical to mount them on iron carriages. The Committee anticipate that batteries of the above nature should be made in the curtains* to contain about five guns each, forming a total of 40 guns.

The nature of the ground around the fort, renders vertical fire from mortars very desirable, and the Committee would point out the following sites as good positions for batteries :—

First.—In the south-east angle of the Fort near the Jehangir Muhul, from which shells may be thrown into the broken ground on the south and across the river, a *second* battery might be placed near the present barracks, and a *third* on the grand parade.

These positions would be taken up, on the necessity occurring, but mortars of the heaviest calibre, for the armament of the place should, be specially retained in the fort.

The Committee would limit the armament of the *fausse braie* to the formation of batteries in the bastions of the outworks in front of the gateways, as in any other parts the *fausse braie* is so narrow, and the main walls so high, that the batteries would be untenable from the splintering of the stones under the enemy's shot.

The ordnance should be as follows :—

At the Ummur Singee gateway, three guns and one howitzer, in each bastion.

At the Delhi gateway, a similar armament.

* The curtains, one on each side of the Ummur Singee gate, and one on each side of the Delhi gate—also to the right and left of the Futeh Boorj on the north, and the curtain of Ummur Singee outwork, and one on the water face where found practicable.

The armament of the new works outside the Fort, should be as follows —

For the two new bastions on the river face —

IN EACH BASTION,	1 8-inch howitzer, 1 24-pounder gun,	per flank
	1 8-inch howitzer, 2 24-pounder guns,	per face

For the Counterguard north front, two 24-pounders in the east flank, to sweep the face of the proposed new bastion One howitzer, 8-inch, and one gun in west flank, to cover the Jumma Musjid and city

For the Jumma Musjid outwork For the front, three guns, to sweep the ravine, leading right upon it and the neighbouring suburbs, and two guns in each of the three remaining sides

For the Ravelin in the south-west part, field guns and howitzers only are deemed necessary The faces and flanks should be pierced with embrasures for ten or twelve pieces, say two in each flank, and three or four in each face

ABSTRACT OF ARMAMENT

Body of the place,	8-inch shell guns in bastion,	8
	Siege iron guns in casemates,	40
	13 and 10-inch mortars,	12
Fausse braie,	Siege iron guns, 24-pounders,	12
	8 inch howitzers,	4
River bastion,	24 pounder iron guns,	12
	8 inch howitzers,	4
Counterguard,	24 pounder iron guns,	3
	8-inch howitzer,	1
Jumma Musjid,	24-pounder iron guns,	5
	8 inch howitzers,	4
	Total Iron Guns,	105
Ravelin,	9-pounder brass field guns,	8
	24- " " howitzers,	4
	Total Brass Guns,	12

with a proportion of field guns, and 5½-inch brass mortars available, as circumstances may demand their use

---

From the Secretary to the Government of India, with the Governor General, to the Secretary to Government, N W Provinces, P. W Department

Benares, 8th December, 1860

SIR,—The Governor General having had before him the report of a

Committee, convened under orders from this department in December last, on the improvement of the defences of the Fort of Agra, with reference to the contemplated removal to that place of the arsenal establishments from Delhi, has come to the conclusion that the great cardinal object of reducing to the smallest dimensions all strong places, the retention of which is a necessity so long as we retain India, has not been sufficiently kept in view by the Committee

His Excellency is of opinion that the outworks proposed by the Committee, are objectionable as rendering it necessary to maintain a larger garrison, and being in themselves a source of weakness rather than of strength

The irregular ground outside of the Fort, should, as recommended by the Committee, be sloped off, so as to present a succession of glacis, and expose the whole extent as much as possible to the view and fire of the fort

A glacis and covered way should be formed, the counterscarp being strengthened by counterforts where necessary, to make it support the additional weight of earth

The Jumma Musjid should neither be destroyed nor occupied, but mined so as to admit of its being blown up in case of necessity Embrasures, not concentrated in batteries, but scattered, should be pierced in the walls, so as to give a fire at a lower level than from the top of the walls

To carry out the above measures, the Military Department has been this day requested to move His Excellency the Commander-in-Chief, to place a company of Sappers under an intelligent officer, at the disposal of the Superintending Engineer, and I am to request that His Honor the Lieutenant Governor, will have the goodness to authorize the Superintending Engineer to allow the officer in question to draw funds to the extent of one thousand rupees per mensem, from the Executive Engineer, for laborers to be employed under the supervision of the Sappers, and for materials and miscellaneous expenses connected with the works He should of course be required to furnish proper accounts, and to report progress of work.

I am further to request that the Public Works and Civil Officers may be called upon to submit estimates of the cost of removing Jotee Persad's house, situated on the northern side of the fort, and for effecting a clearance round the Jumma Musjid.

A report is likewise required from the Superintending Engineer, as to whether space could be found in the fort, to erect two or more earthen cavaliers, on which the garrison could in case of need, place batteries which would enable them to return the fire of assailants, after the masonry walls should have been so injured as to be incapable of bearing guns

A further report by the Superintending Engineer is requested, as to the armament that will be necessary for the fort, with reference to the above contemplated arrangements

The Committee have selected the Meena Bazar, as the site for the powder magazine This has the approval of the Governor General, but the estimate for the work may be deferred until the arrangements in regard to the ordnance magazines in the Agra fort, shall have been settled in the Military Department, so as to define the accommodation to be retained for that purpose

C H DICKENS

No XVII

MACHINES FOR RAISING WATER

Calculation of the Labor and Cost of Raising Water by the different Machines employed in India by the Natives BY SERGEANT J WEBSTER, *Assistant Master, Thomason College*

THE heights assumed for raising the water in each case are those for which it is believed the several machines could be most generally and usefully employed

The value of the modulus and the useful effect in each case are assumed after due consideration of the structure of each machine and the amount of spillage or waste

1 THE BEAM AND BUCKET

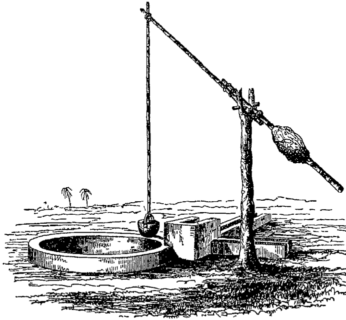
(One man employed)

Water raised 16 feet
Content of bucket = 45 cubic feet = 2 8 gallons
Average time of raising the bucket = 20 seconds
Number of discharges per minute = 3
Discharge per minute = 3 × 45 = 1 35 cubic feet = 8 4 gallons.
Discharge per hour = 81 cubic feet = 506 gallons
If we take the useful effect or discharge at 90 per cent, we get—
Actual discharge per hour = 72 9 cubic feet = 455 4 gallons

2 BALING

(Two men employed)

Water raised 5 feet
Deliveries in each minute = 20



THE BEAM AND BUCKET

BAILING.

One delivery $= \frac{1}{3}$ cubic foot $=$ 2 1 gallons
Delivery per minute $= \frac{20}{3}$ cubic feet $=$ 42 gallons
Delivery per hour $=$ 400 cubic feet $=$ 2520 gallons
Useful effect $=$ 75 per cent, then—
Actual discharge per hour $=$ 300 cubic feet $=$ 1890 gallons

3 The Single Môt

(One man and two bullocks employed)

Water raised 40 feet
Speed of bullocks $=$ 2 miles an hour
Space gone over by the bullocks at one lift $=$ 80 feet
Content of bag 3 cubic feet $=$ 18 75 gallons
Weight of water raised at each lift $=$ 187 5 pounds
Time required for bullocks in turning $=$ 4 minute
Speed of bullocks per minute $= \frac{5280 \times 2}{60} =$ 176 feet

Therefore time required to pass over 80 feet $= \frac{80}{176} =$ 45 minute,
and time required for one lift $=$ 45 $+$ 4 $=$ 85 minute
Number of lifts per minute $= \frac{1}{85} =$ 1 18.
Discharge per minute $=$ 1 18 $\times$ 3 $=$ 3 54 cubic feet $=$ 22 gallons
Discharge per hour $=$ 213 6 cubic feet $=$ 1320 gallons
Useful effect $=$ 70 per cent
Actual discharge per hour $=$ 149 5 $=$ 924 gallons

Taking the modulus $=$ 9 and the weight of the rope and bag $=$ 42 pounds, the required traction which the bullocks have to overcome is $= \frac{187\ 5 + 42}{9} = \frac{229\ 5}{9} =$ 255 pounds, and one bullock $=$ 127 pounds

4 The Double Môt

(One man and bullock employed)

Water raised 40 feet
Speed of bullocks $=$ 2 miles an hour
Speed of bullocks per minute $=$ 176 feet
Diameter of barrel $=$ 3 feet
Diameter of bullock walk $=$ 16 feet

Length of bullock walk $= 16\pi = 50·2$

Number of turns of bullock per minute $\frac{172}{50·2} = 3·4$

Turns required for drawing up the bag $= \frac{40}{3\pi} = 4·25$

Time required for drawing up the bag $= \frac{4·25}{3·4} = 1·2$ minute

Time for disengaging the barrel and lowering the bag $= ·2$ minute

Total time for raising up the bag $= 1·4$ minute

Content of bag $= 3$ cubic feet $= 18·75$ gallons

Discharge per minute by one bag $= \frac{3}{1·4} = 2·1$ cub ft $= 13·4$ gallons

Discharge per minute by 2 bags $= 4·2$ cubic feet $= 26·8$ gallons

Discharge per hour by 2 bags $= 252$ cubic feet $= 1608$ gallons

Useful effect $= 65$ per cent

Actual discharge per hour $= 165·8$ cubic feet $= 1045$ gallons

Space moved over by the bag at one revolution $= 3\pi$

Space moved over by the bullocks at one revolution $= 16\pi$.

Ratio of power and weight $= 3 : 16$ or $1 : 5·3$.

Weight of water contained in 2 bags $= 375$ pounds

Weight of bags and ropes $= 85$ pounds

Total weight to be raised $= 460$ pounds

Taking the modulus $= ·7$, we get—

Work applied $= \frac{460}{·7} = 657$ pounds

Required traction $= \frac{657}{5·3} = 124$ pounds

5 The Single Persian Wheel

(One man and two bullocks employed.)

Water raised 40 feet

Diameter of driving wheel $= 4$ feet

Diameter of bucket wheel $= 4$ feet

At each turn of the bullocks, 6 buckets are emptied, and assuming the content of each bucket $= \frac{1}{8}$ cubic foot, we have—

Discharge at each turn $= \frac{6}{8} = \frac{3}{4}$ cubic foot $= 4·7$ gallons

Length of bullock walk $= 20\pi = 62·8$ feet, and speed of bullocks $=$ 2 miles an hour, we get—

Speed of bullocks per minute $= 176$ feet

Number of turns per minute = 2 8

Discharge per minute = 2 8 × $\frac{3}{4}$ = 2 1 cubic feet = 13 gallons

Discharge per hour = 126 cubic feet = 780 gallons

Useful effect = 55 per cent

Actual discharge per hour = 69 3 = 429 gallons

Buckets are 2 feet apart

Number of buckets required = 40

Weight of buckets = 80 pounds

20 buckets being always full, the weight of the water they contain is $= \frac{20 \times 62\ 5}{8} = 156$ pounds

Weight of rope = 22 pounds

Total weight to be raised = 258 pounds

Space moved over by the buckets at one revolution = 4π

Space moved over by the bullocks at one revolution = 20π

Ratio of power and weight = 1 : 5

Modulus = 0 6

Work applied $= \frac{258}{6} =$ 430 pounds

Required traction $= \frac{430}{5} = 86$ pounds

TABLE SHOWING THE COMPARATIVE PERFORMANCE AND COST OF THE ABOVE MACHINES IN RAISING WATER TO THE SAME HEIGHT (40 FEET)

The expense of a laborer is put down at 2 annas and of a bullock at 4 annas per diem. Duration of work per diem = 8 hours

No	Methods	Stages	Useful effect per cent	Discharge per hour		Discharge per diem.		Ratio of dis charges	Employs		Daily expense	Quantity of water raised for one rupee		Remarks.
				Cubic feet	Gallons	Cubic feet	Gallons		Men	Bullocks	Annas	Cubic feet	Gallons	
1	Beam and bucket,	2 5	90	29·07	181 4	232 5	1451 5	1	2		4	930	5806	Discharge increased with decrease of height
2	Baling,	8	75	37 5	236 2*	300	1875	1 29	4		8	600	3750	Ditto
3	Single Mot,	1	70	149 5	924	1196	7392	5 1	1	2	10	1911 8	11827 2	Discharge increased with decrease of height
4	Double Mot,	1	65	165 8	1045	1326 4	8360	5 7	1	2	10	2096 6	13478 5	Ditto
5	Single Persian Wheel,	1	55	69 3	429	554 4	3432	2 4	1	2	10	857	5491	Discharge the same at any height

The cost and wear of the machines are not taken into consideration.

* Being one-eighth of the quantity raised 5 feet high, as computed at p 168

J WEBSTER.

No XVIII

SOHAN BRIDGE—LAHORE AND PESHAWUR ROAD

Designed and now being constructed by LIEUT-COLONEL ALEXANDER TAYLOR, C B, R E

To The Chief Engineer and Secretary to Government, Punjab, P W D

Murree, 7th May, 1862.

SIR,—I have the honor to submit a revised design and estimate for a bridge over the Sohan river The work proposed is entirely of masonry, and is less expensive than a bridge having masonry piers and timber superstructure with the same width of roadway and same waterway

The area drained by the Sohan at the site of the bridge is about 573 square miles, and is very compact in shape The greatest depth of the river in floods is 15 feet, and the mean velocity about 8 or 9 feet per second The slope of the bed is at the rate of 14 feet per mile The calculated mean velocity is 13 feet per second The discharge calculated from cross sections of the stream, is in extreme floods about 91,000 cubic feet per second, which is equivalent to about $\frac{1}{4}$th of an inch over the entire catchment basin The bed of the river exposed to view consists of boulders, water flows all the year round, and is never less than 1 foot in depth The true bed of the river is no doubt the hard red clay of the country, over that may be expected a layer of blocks of conglomerate, and over that some 12 or more feet of boulders

In the design proposed, the foundations of the drop walls, and of the piers and abutments are all carried through the boulders and conglomerate blocks, and rest on the hard clay

At the site selected for the bridge, the river is rather wide, being over 1000 feet, while a few hundred feet higher up, the width does not exceed 750 feet (*See* accompanying plan) The clear water-way of the bridge is 945 running feet

The excavation of the foundations in accordance with the design now submitted is being vigorously proceeded with, and I hope that a good deal of the foundation masonry will have been executed by the beginning of the rains The excavation is now $11\frac{1}{2}$ feet below water, and the influx of water is under 80 cubic feet per minute, while we have means ready to pump out double that quantity At 11 feet we have met with the tops of some conglomerate blocks which renders it probable that the depth to the clay bottom assumed at 16 feet will suffice

The tramway bringing stone from the quarry is in full work

The Governor General has already expressed his approval in regard to the leading features in this design, that is, the width of road-way and the substitution of masonry for timber For foundation work, the present and the next months are very valuable, and this coupled with the fore-gone approval to the change in design, has induced me to push on with the work in anticipation of final sanction

The cost of a timber bridge without any flooring was estimated at Rs 4,50,000

The cost of the masonry bridge with flooring, and in all respects complete, is estimated at Rs 4,28,271

Early intimation of sanction to this design is requested, that arrangements may be made for the supply of the large number of bricks that will be required

REPORT

The original design consisted of 10 spans of 100 feet each The superstructure was of timber on masonry piers, and the bridge was not floored The design now submitted consists of 15 spans of 63 feet each, entirely of masonry, and the bridge is floored throughout It is less expensive than the original design with the same waterway, and same width of roadway.

SPECIFICATION

The foundations to rest throughout on the clay bottom of the river

The masonry below the flooring to be of coursed rubble, the faces not to be dressed The floor to consist of large blocks of stone well fitted, and the end stones to be of the largest size and cut to fit closely

From the floor to the spring of the arches the masonry to be of the best coursed rubble in large blocks with dressed faces The imposts to be accurately cut

The arches, spandrel walls, and superstructure of parapets to be of best brick-work The cornice to be of cut stone The surface drainage of roadway to be discharged through the crown of each arch, by an iron pipe just clear of the wheelguard

The entire surface of the roadway to be metalled with broken stone

The stone to be used is sandstone, from the quarry on the Leh Nullah, and none but the very best quality of stone is to be put into the work

---

ABSTRACT OF ESTIMATE

c ft.		R	A	P
1,56,694	Cut brickwork, at Rs 35 per 100,	54,842	9	0
21,924	Cut stone masonry, at Rs 50 per 100,	10,962	0	0
3,04,271	Rubble masonry in superstructure with dressed faces, large blocks, at Rs 25 per 100,	76,067	7	0
3,24,844	Rubble masonry in foundations, at Rs, 22 per 100,	71,465	7	0
22,03,500	Excavation for foundations in boulders and water, at Rs 20 per 100,	44,070	0	0
61,00,000	Excavation in drainage cuts, partly dry and partly in water, at Rs 9 per 100,	54,900	0	0
15,522	Boulders for metalling, at Rs 2 per 100,	310	4	0
15,522	„ to be broken, at Rs 3 per 100,	465	7	0
15,522	„ „ consolidated, at Rs 1 per 100,	155	2	0
15	Centerings, at Rs 1,600 each,	24,000	0	0
	Pumping and pumping machinery,	60,000	0	0
29	Iron drainage pipes, 4 inches thick, at Rs 22 each,	638	0	0
	Probable loss on ironwork prepared in furtherance of original design, being one-third of cost,	10,000	2	0
	Total,	4,07,877	6	0
	Contingencies at Rs 5 per cent.,	20,393	8	0
	Grand Total,	4,28,271	0	0

A TAYLOR, LIEUT.-COLONEL,

Superintendent, Lahore and Peshawur Road

No XIX

REPORT OF THE OPERATIONS OF THE GREAT TRIGONOMETRICAL SURVEY OF INDIA, DURING 1862-63

By Major J T Walker, R E, *Superintendent G T Survey*

To the Secretary to the Government of India, *Military Department*

Dehra Doon, 1st September, 1863

Sir,—I have the honoi to 1epoit the progress of the Tiigonometiical Survey during the past official yeai

In accordance with the sanction of Government, I proceeded, in the autumn of 1862, to Vizagapatam to measuie a Base line Vizagapatam is situated nearly on the same paiallel of latitude as Bombay, and is the point wheie the Bombay longitudinal seiies, when extended eastwaids to the Madias coast, will terminate This series of tiiangles will foim, with the Gieat Aic Meiidional, the Calcutta Longitudinal, and the coast seiies, a vast quadiilateral figure, ciicumsciibing the meridional seiies of tiiangles which are requiied as a basis foi the interior topogiaphical details Base lines had been measured several years ago, by Colonel Eveiest, at Bedai, Seionj, and Calcutta, the S W, N W, and N E angles of this quadiilateral One moie Base line remained to be measured, which foi consideiations of symmetiy it was desirable to place in the vicinity of Vizagapatam

Captain Basevi, the officei in charge of the coast series, being located at Vizagapatam, was diiected to select the site After several trials, owing to the difficulty of carrying a stiaight line, seveial miles in length, so as to avoid the numerous iiiigation tanks with which this district is studded, he eventually succeeded in finding a suitable line on the undulating plain between the military stations of Vizagapatam

secondary triangles, 19,096 square miles, the cost, Rs 1,08,21 2, which gives a rate of Rs 5-10-8, or about 11 shillings per square mile

The Sutlej series follows the left bank of the Sutlej from its junction with the Indus, near Mithunkote, to a side of the Gurhagurh series near Ferozepoor It was commenced towards the close of field season 1860-61, by Lieutenant Herschel and was completed last season by Mr Shelverton It is single throughout The recess computations will be completed by 1st October, when the party will be transferred to the meridian of 80°, to execute the required triangulation between Jubbulpoor and Madras During the past field season the triangulation extended over a distance of 112 miles, covering an area of 1,366 square miles A very creditable amount of secondary triangulation was also executed The total cost of the series, up to 1st October, the date of its completion, will be about Rs 80,743, the total area covered by the triangulation is 8,142 square miles, thus giving a rate of Rs 9-14-8, or, nearly 20 shillings per mile

The Bombay party, under the superintendence of Captain Haig, Royal (Bombay) Engineers, having completed the triangulation in northern Bombay, was deputed to execute a series of triangles to the south of the parallel of Bombay, on the meridian of Mangalore While the preliminary operations and selection of stations were proceeding, Captain Haig marched to the origin of the Bombay longitudinal series, with a view to making this series double throughout, by adding flank stations so as to form polygons in parts where there were only single triangles On reaching the ground, it was found that the ends of the Beder Base line were, fortunately, in good preservation Three of the advanced stations had, however, been completely destroyed Captain Haig judiciously determined to triangulate the series anew as far west as the Mangalore meridian The revision having been executed with a much superior instrument to that employed in the original triangulation, the value of this portion of the Bombay Longitudinal series is very greatly enhanced

Having completed this revision, Captain Haig was proceeding with the principal triangulation on the meridian of Mangalore, when an untoward accident brought his operations to an abrupt termination The large theodolite was set up for observation on the tower station of Palwan, when, without any previous warning, the tower gave way on one side, causing the fall of the instrument and observatory tent, whereby the

instrument was so seriously injured that it is incapable of being again used, until it has been repaired by the makers in England. Fortunately, the horizontal circle, the most valuable portion, appears to have escaped injury, but the vertical circle was destroyed, and the injuries are such that the instrument cannot be repaired in this country. Capt. Haig convened a Court of Enquiry to report on the circumstances, the proceedings of the Court have already been submitted to Government. The Court came to the opinion, in which I entirely concur, that the fall of the tower was was occasioned by the sudden and unexpected sinking of the ground below, and that no blame is attributable to Captain Haig or any other person, for the mishap.

Captain Haig had already turned out a very excellent season's work, comprising thirty-two principal triangles, covering an area of 6,625 square miles, and extending over a length of 260 miles, whereof 66 appertain to the Mangalore meridian, and 191 to the parallel of Bombay.

The Spirit Levelling operations were carried on by Mr. Donnelly, Civil Second Assistant, under the superintendence of Lieutenant Thuillier. The party accompanied me to Calcutta, to receive the necessary instructions regarding the programme of the seasons's operations, which could not be decided on until I had obtained reliable information regarding the Railway levels between Calcutta and Agra. I had hoped to be able to incorporate these into our work, so as to avoid the labor and expense of carrying a line of levels all that distance. During the previous field season, a connection had been made at Agra, with the Railway levels brought up from Calcutta, and the G. T. Survey levels, brought up from the mean sea level at Kurrachi. The two sets of results differed by about twenty-four feet, and it was hoped that all difference would disappear, on connecting the Railway datum,*the site of Howrah Dock, with the mean sea level of the Bay of Bengal.

That level had already been closely ascertained, by a series of tidal observations taken at Kydd's Dock, and subsequently verified by others taken at Kejri, from the description of which (*vide* foot-notes) it is evident that the mean sea level of the Bay of Bengal may be considered to be known, to within a few inches of the truth.* On connecting the

* The following description of the connection of Kydd's Dock with the mean sea level of the Bay of Bengal is taken from a Report, dated 1st November, 1854, on the Calcutta Meridional Series, by Colonel Waugh, Surveyor General and Superintendent G. T. S. —

" A register of the tides in the river Hoogly is regularly kept at Kydd's Dock yard, near Calcutta,

Railway levels with Kydd's Dock, it was found that there still remained

the height of each successive tide being referred to a fixed datum line or zero which is the bottom or sill stone of the dock, and therefore an object of invariable character.

"A transcript of the register of the tides for two years, viz., from May 1816 to April 1818, having been obtained from the Marine Department, a monthly abstract of mean tide was deduced therefrom.

"The waters of the ocean would maintain a constant level if undisturbed by the action of the sun and moon. La Place has demonstrated that this level is a mean between the highest and lowest state to which the surface of the ocean is reduced by the attraction of those bodies. This mathematical truth is corroborated by observations made on open coasts, from which it results that the mean of high and low water for two consecutive tides represents very nearly, the level of the sea, and that the average for a lunation is constant within a very small quantity. — *Vide* Professor Whewell's Report, Vol. VII., British Association's Report.

"An examination of the abstract of monthly mean tides will, however, show that considerable irregularity exists in the river Hoogly, the monthly means differing as much as six and a half feet. Now if the annual average be considered as the true level of the sea, it would follow that for some months, consecutively, the mean height of the river is two and a half feet below the sea level, a conclusion which is altogether inadmissible.

"The lowest monthly mean tide occurs about February and March, when the fresh water in the river is lowest, and strong Southerly winds do not prevail. The mean tide rises gradually, as the river rises during the south monsoon, until it attains its maximum, in September or October, at which time the monthly mean exceeds that of February by no less than six feet. This rise is, obviously, the effect of accumulation, produced by inundation in the Valley of the Ganges, and the force of the S. W. wind, which dams up the freshes in the long and narrow channel of the river.

"It has been remarked by Colonel Cheape, Chief Engineer, in his memoirs dated April 1825, that the surface of the Salt Water Lake, wherein the rise of the tide is almost imperceptible, would on account of its wide expanse, represent very accurately the level of the sea with which it communicates. He also observes that Captain Taylor's levels indicate that the surface of the lake in the dry season is 2 feet 4.3 inches below the mean state of the river. This result corresponds very nearly with the mean tide of the river itself, which in February is 2 feet 5 inches below the level of the annual mean.

"Colonel Cheape further states that the periodic rise of the surface of the lake in the wet season is ten inches. Now, the contemporaneous rise in the mean tide of the river has been shown to be six feet, and as the cause of these elevations is precisely the same, though the effects are in the ratio seven to one, the greater rise in the river can clearly be attributed only to the narrowness of its channel compared with the bay. It is probable that a considerable portion of the rise of ten inches in the surface of the lake is also due to accumulation, so that although a rise may be supposed to take place in the level of the sea at the head of the bay, during the continued pressure of the S. W. monsoon, still, that elevation must be much less than what takes place in the lake, where the effect of this rise is increased by the narrowness of the channel, and the influx of fresh water during the inundation.

"It has been shown, that if the annual average of mean water be taken as the sea level, it would lead to the inadmissible conclusion that in the dry season, the average level of the river at Calcutta is twenty nine inches below the sea, with which it freely communicates. It has also been shown that the surface of the great Salt Water Lake in the dry season, is on a level, or nearly so, with the mean tide of the river at the same time. It is likewise manifest that the periodic rise of mean tide during the monsoon, to the extent of six feet in the river and ten inches in the lake is occasioned by local causes, independent altogether of the true level of the sea, which is a constant level, and these causes, it appears, operating in narrow channels are capable of producing exaggerated results in the proportion of seven to one, showing clearly the fact of accumulation. Hence the conclusion is inevitable, that the lowest monthly mean tide of the river, observed in February and March, represents the nearest approximation to the actual sea level, and that the rise of mean tide at Calcutta during other months may fairly be ascribed to disturbing causes of an inland character, altogether independent of the true and constant level of the ocean. The variable character of the disturbing causes is shown by the fact that the monthly means of corresponding months, for the two years differ considerably, except in the months of February and March, the monthly mean tides of which are very accordant.

"Proceeding upon this principle, I have used the following observations to refer the datum line in Kydd's Dock to the sea level :—

a difference of about twelve feet between the Railway and the Survey

"Mean tide February 1847, above datum as measured on gauge,		8 11 feet
" March, " " " "		8 15 "
" February 1848, " " "		8 18 "
" March, " " " "		8 20 "
" February 1850, " " "		8 28 "
" March " " " "		8 62 "
" February 1851, " " "		7 94 "
" March, " " " "		8 26 "
	Mean,	8 342 feet

"Correction for error of graduation on gauge by Mr Bedford's measurements, 0 .76 "

"By tides measured at Calcutta in February and March, mean sea level above datum, 8 576 "

"Again, in the years 1850 and 1851, Mr Bedford, the Marine Surveyor, took a series of tidal observations at Kejiri and connecting this point by a series of levels with Kydd's Dock, found the datum line at the latter point is 9 07 feet below the sea level Mr Bedford's observations, from which this result is derived, are as follows —

MEAN LEVELS OF THE RIVER'S MOUTH AT KEJIRI, AT NEAP TIDES, FOR THE YEARS 1850 AND 1851, EXCLUDING THE SOUTH WEST MONSOON

Months	Highest Low Water		Lowest High Water		Mean	
1850	ft	in	ft	in	ft	in
January,	5	0	11	9	8	4½
	4	0	11	9	7	10½
February,	5	6	11	0	8	3
	4	9	11	6	8	1½
March,	6	0	11	0	8	0
	4	9	12	0	8	4½
April,	6	9	11	0	8	10½
	4	9	12	6	8	7½
May,	6	9	12	0	9	4½
	5	3	13	0	9	1½
June,	6	6	13	3	9	10½
	6	0	14	9	10	4½
November,	7	0	13	3	9	7½
	4	9	13	0	8	10½
December,	5	9	11	9	8	9
	4	6	12	3	9	4½
1851						
January,	4	6	11	9	8	1½
	4	3	11	0	7	7½
February,	4	3	11	3	7	9
	5	0	10	3	7	7½
March,	4	9	11	0	7	10½
	6	3	11	9	9	0
April	5	3	12	9	9	0
	7	0	10	6	8	9
May,	5	6	12	6	9	1½
	7	0	12	9	9	9
June,	6	0	14	6	10	3
	6	0	13	3	10	0

	ft	in
"Mean height of sea level above the datum line at Kejiri,	8	9 75
"Datum line at Kejiri above that of Kydd's gauge,	0	2 88
"Sea level above the datum line of Kydd's gauge,	9	0 63
"Which reduced to decimals of a foot, becomes,		9 053

"Which differs from my determination by half a foot but if the tides at Kejiri for February and March be alone taken into account, at which period the inland waters flowing seaward are lowest, the result would agree with that derived from my discussion of the tides at Calcutta to about one inch"

height of Agra.* On discussing this subject with the Chief Engineer of the Railway, I ascertained that there were several breaks in the Railway levels, that, in consequence of the pressure of other work, there had been no opportunity of preparing a correct and true section of the whole line, and that it was contemplated to re-level the line, as soon the Engineers had leisure to do so. I decided, therefore, on deputing the levelling party to re-level the line of the Railway, and connect all the Trigonometrical Stations within reach thereof.

Mr. Donnelly made good progress, and accomplished two hundred and forty-two miles of first-class levelling† forty-one of which had to

* Mr. Donnelly reports that he was much delayed by the discrepancies which were found between his levels and those of the Railway. They entailed the re-measurement of two sections, one fifteen, the other twenty six miles in length. In the first, the discrepancy was five feet, in the second seventeen and a half feet. Mr. Donnelly and his Assistant re-measured both these sections and obtained results differing from their first results by only 0·92 of a foot in the first instance, and 043 in the second, clearly showing that the error did not lie in their work.

In the course of the Field Season, Mr. Donnelly laid down nine G. T. S. Bench Marks, fixed two G. T. S. Trigonometrical Stations, and connected one hundred and forty one points, principally Railway Mile stones, Bridges, Bench marks, and Station Platforms.

COMPARISON OF RAILWAY AND G. T. SURVEY LEVELLED HEIGHTS.

Names of Railway Stations and Bench marks	G. T. Survey		Railway	G. T. S. — Railway	Remarks
	Height above Mean Sea Level	Height above Howrah Dock Sill	Height above Howrah Dock Sill		
Serampoor,	+ 20 910	+ 32 552	+ 32 230	+ 0 322	Level of Rails
Pundooa,	+ 42 398	+ 54 031	+ 54 140	+ 0 100	Do
Dymaree,	+ 66 69[illegible]	+ 78 380	+ 78 260	+ 5 070	Do
Burdwan,	+ 100 325	+ 111 958	+ 107 260	+ 4 698	Do
Kanoo Junction,	+ 121 439	+ 133 172	+ 128 250	+ 4 922	Do
Gooskarrah,	+ 110 948	+ 122 137	+ 118 250	+ 3 887	Do
Beddiah,	+ 132 270	+ 143 903	+ 140 250	+ 5 663	Do
Bulpoor,	+ 166 635	+ 171 268	+ 167 250	+ 4 018	Do
Ahmadpoor,	+ 134 213	+ 145 846	+ 142 250	+ 3 596	Do
Cynthea,	+ 168 330	+ 179 963	+ 176 250	+ 3 713	Do
Dullarpoor,	+ 143 709	+ 155 362	+ 151 230	+ 4 112	N. W. Plinth of Station house
Rampoor Haut, B. D.,	+ 116 810	+ 128 143	+ 124 960	+ 3 483	Square Pillar in centre of Line, opposite Booking office
Pakowr,	+ 104 392	+ 116 025	+ 112 250	+ 3 775	Level of Rails
Teenpahar,	+ 103 770	+ 115 422	+ 129 250	− 13 838	Do
Tilliaghurree, B. D.,	+ 110 900	+ 122 583	+ 135 830	− 11 800	Square Pillar on Line to E., marked D
Do	+ 96 638	+ 108 271	+ 121 090	− 12 809	Heel Stone of Gateway, W. Gate of Fort N. side, original B. D.

† With an Assistant levelling the line independently, behind him, station by station, after the method described in the published volume of Tables of Heights.

be re-levelled, on account of large discrepancies which were found in the Railway levels. The operations had reached the vicinity of Bhagulpore, when Mr Donnelly was compelled, by severe illness, to close work.

During the year under review, I was called upon to collect all the available data of levels, existing in the Public Works, Railway, and Survey Offices, all over India, in order to reduce them to a common datum. As a first step towards this desirable measure, I have published a volume of Tables of Levels, based on the Spirit-Levelling operations of this Survey, and reduced to the mean sea level of Kurachi harbour, as their datum. Additional volumes will be published as soon as possible. They will enable Officers of the Public Works and Railway Departments to reduce their levels to the mean sea, by connecting them with the nearest Bench-mark, or Station of the Trigonometrical Survey. In most instances, however, the business of connecting will probably devolve on the Survey Department. At present, we have only one Levelling party, which is employed in Bengal; I therefore submitted a project for the formation of other parties, to carry on operations, simultaneously, in the Madras and Bombay Presidencies, as the only means of speedily accomplishing an operation, of which the practical value will be greatly enhanced by early completion. Unfortunately, financial reasons have interfered to prevent this proposal from being sanctioned.

I now proceed to report on the Astronomical Observations for the determinations of the Latitude and Longitude of the Andaman Islands, which were instituted on a representation by the Superintendent of Port Blair, that the erroneous positions assigned to some of these Islands, in the published Charts, endangered the safety of ships sailing between Calcutta and Singapore. Under the orders of Government in the Home Department, the Surveyor General had deputed a Surveyor, Mr Nicolson, to conduct the necessary observations, the superintendence of which was subsequently transferred to the Trigonometrical branch of the Survey.

Mr Nicolson started from Calcutta early in December 1861, to reconnoitre the Coco and Andaman Islands. He found that, in order to take a complete Series of Astronomical Observations at the great Coco, it would be necessary to have a steamer placed at his disposal for some weeks to keep up his communication with Port Blair, and bring the necessary supplies for his party.

About this time, a communication was received from the Bombay Government, representing that there was as much doubt about the accuracy of the position of Port Blair, as of that of the Coco Islands

Under these circumstances, it seemed advisable that Mr Nicolson should begin operations by fixing Port Blair, in order that the proposed operations might be commenced at the place where the greatest facilities for their execution existed

The inaccuracy of the present Charts of the islands lying between Sumatra and Burma being admitted on all sides, it appeared necessary, in the absence of any regular survey of those islands to fix, by astronomical observations, the positions of Acheen Head, Port Blair, the Great Coco, or the Preparis Island, and an island in each of the other groups intermediate between Acheen Head and Cape Negrais It is believed that the relative positions of the mutually visible islands of each group are already correctly shown on the Charts, consequently, by determining the absolute position of a point in each group, it would be possible to rectify the existing Charts, without making a general re-survey

Mr Nicolson, having completed his reconnoissance, returned to Calcutta in February 1862, by which time one of the large 3-foot astronomical circles of the Trigonometrical Survey had been got ready, and a portable observatory, with rotating dome, constructed for the observations There was no good astronomical telescope available in the stores of the Mathematical Instrument Department, consequently, Mr Nicolson was directed to take all his observations, whether of occultations, eclipses, or moon culminations, with the telescope of the astronomical circle, which he could point to any part of the sky through the aperture in the rotating dome of the observatory Owing, however, to the small number of occultations and culminations which occur monthly, and the risk of losing some of them in cloudy weather, Mr Nicolson was directed to base his observations for Longitude chiefly on the measurement of lunar zenith distances, for which the astronomical circle is well adapted He was supplied with an astronomical clock, and all other necessary instruments, from the Calcutta observatory

In May 1862, Mr Nicolson had set up his observatory at Port Blair, and was ready to commence observations Unfortunately, the season of fine weather had then nearly terminated, the monsoon set in with unusual severity, nights favorable for observing were few and far between, and,

consequently, several months elapsed before the whole of the necessary observations for Latitude and Longitude were completed The work was further impeded by the delays attendant on postal communication between Calcutta and Port Blair, making it very difficult for me to exercise that degree of supervision over the operations, which their delicate and difficult nature required

By the end of 1862, Mr Nicolson reported that he had taken a sufficient number of observations to fix the position of Port Blair, he, therefore, applied for a vessel to be placed at his disposal to enable him to proceed to fix the positions of the Great Coco, and other islands Owing to postal and other delays, it was not until the end of February 1863, on my return from Vizagapatam, that I learnt from the Marine Department that no vessel was available, nor could one be got ready before the fine weather season would have terminated

From the same communication I also learnt that the Secretary of State for India had ordered a complete Maritime Survey of the Andaman Islands to be executed Being then in Calcutta I went to Captain Rennie, the Secretary to Government of India, Marine Department, and was informed that, under instructions from the Admiralty Hydrographer, it had been determined to find the differences of Longitude beween the various groups of islands, chronometrically, by a battery of thirteen or fourteen chronometers

The circumstances under which it was originally proposed to fix a series of positions by astronomical observations had thus entirely altered The complete Maritime Survey, which has been ordered by the Right Hon the Secretary of State for India, renders further astronomical observations unnecessary The determinations of differences of Longitude, which are the only really difficult portion of the work, can be done chronometrically by the Marine Surveyors, with much greater rapidity and economy, and probably even with greater accuracy, than by the best astronomical observations for absolute Longitude

Consequently, in March last, I desired Mr Nicolson to restrict his operations to taking as many more observations for the determination of the Longitude of Port Blair, as could be obtained before the setting in of the monsoon, and then to return to Calcutta He reached the Presidency in June, and has ever since been employed in reducing his observations. They consist of 32 lunar culminations, 136 lunar zenith

distances, 130 transits of clock stars, and 162 meridional zenith distances of stars for Latitude, observed up to the 12th March, when the astronomical clock met with an accident, and Mr Nicolson was afterwards obliged to employ a chronometer His subsequent observations are, consequently, not as valuable as the earlier ones, they consist of 9 culminations, 64 lunar zenith distances, and 36 clock stars The whole of the Latitude observations have been reduced, and found exceedingly satisfactory There has not yet been leisure to reduce more than a few of the observations for Longitude, but the results obtained hitherto are satisfactory The final resulting Longitude will be communicated for publication in the *Calcutta Gazette* as soon as ascertained It should serve as an excellent datum for the proposed Maritime Surveys, and save the expense of a series of voyages between Madras and Port Blair, which would otherwise have to be incurred to obtain a good chronometric determination of the Longitude of Port Blair

THE OUT-TURN OF WORK EXECUTED BY EACH PARTY DURING THE FIELD OPERATIONS OF THE OFFICIAL YEAR 1862-63 IS SHOWN IN THE FOLLOWING ABSTRACT —

STATISTICS	Kashmir Series	Coast Series	Sutlej Series	East Calcutta Longitudinal Series	Rahoon Meridional Series	Eastern Frontier Series	* Bombay Party	Total Out-turn of Work
Principal Triangles,		19	29	4	13	16	32	113
Average error of Principal Triangles in seconds,		0".94	0".45	0".44	0".46	0".43	0".89	0".65 average
Observed Azimuths,		1	1		2		1	5
Secondary Triangles with all three Angles Observed,		10	132		16		32	190
Area of Principal Triangulation, square miles,		256	1,366	220	1,603	885	6,625	10,954
Area of Secondary Triangulation, square miles,	10,500		4,816		950	263	1,510	18,139
Area of Topographically Surveyed, scale 4 miles = 1 inch, square miles	10,400							10,400
Intersected Points,		12	112		18	22	110	274
Length of principal Triangulation in miles,			112	20	69	49	260	496
,, Secondary,			340		72		100	512
Miles of rays cleared between Principal Station,			300	253	159			712
Towers built for Principal Stations,			11	5	5		2	23
Platforms,		12			6	17	44	79
Platforms built for Secondary Stations,			95					95
Length of Triangulation laid out in advance in miles,				45		77*	150	272
Principal Stations selected in advance,				8		17	36	61

The Computing Office has been employed in a variety of preliminary operations, which are necessary to form the basis of a general reduction of the whole of the principal triangulation of this Survey, which will shortly become necessary, now that almost the whole of the triangulation of the tracts of country comprised in the great quadrilateral figure connecting Calcutta, Kurachi, Attok, and Purnea, is completed Though the triangulation has been executed with the very best instruments, and though the system of observation which was introduced into this Department by Colonel Everest is more rigorous and accurate than that of any European Survey, it is evident that, in consequence of the vast length of each Series, and the imperfections which necessarily attend whatever is the work of human hands, each Series generates a certain amount of error, which becomes apparent as linear error on the termination of the Series on a measured Base line, while on the close of a circuit formed by two Meridional Series, and the portions of the connecting Longitudinal Series at their extremities, it produces errors of Latitude, Longitude and Azimuth The dispersion of these errors in such a manner as to obtain the most probable results of the whole, giving its due weight to each fact of observation, and taking into consideration the bearing of every such fact on all the rest, is a matter of great intricacy and difficulty, on which it will be necessary for me to consult with the ablest mathematicians of the present day in Europe, before deciding on the system to be finally adopted Meanwhile, the necessary preliminaries for the eventual calculations are being carefully elaborated by Lieutenant Herschel, to whom I am indebted for numerous very valuable suggestions, and for co-operation as cordial as it has been unintermittent

While the practical operations of this department may be confidently pronounced to be of a superior order to similar operations in any other part of the globe, it must, on the other hand, be admitted, that the theoretical applications, for the reduction of the triangulation, have not kept pace with recent improvements in geodetical science, which have been introduced into some European Surveys The method which has hitherto been employed for reducing the observed angles, so as to satisfy all the equations of condition of each figure, though a great improvement on any previous method, has had, in its turn, to give way to the subsequently discovered method of minimum squares The algebraical

solution of the equations necessary to satisfy the condition that the sum of the squares of the errors shall be a minimum, is by no means difficult, but hitherto there has been no practical adaptation of it in this Survey, chiefly owing to the pressure of other and more urgent business, on those alone capable of dealing with the subject Much progress has, however, been recently made in this direction, and I am indebted to Lieutenant Herschel for devising methods of calculation, which will enable the reduction of our figures to be effected, according to the new and rigorous system by native computers possessing little more than a knowledge of arithmetic, with even greater facility than the less refined methods of reduction, which have hitherto been employed

The Drawing Office has been chiefly employed in compiling Maps of the dominions subject to the Maharajah of Kashmir, from the plane table sheets sent in by Captain Montgomerie A new Chart of the Triangulation of this Survey, up to date, has also been prepared, and a Chart to illustrate the volume of Tables of Heights recently published, both these Charts were lithographed in the Office of the Surveyor General, Calcutta Nine original preliminary Charts of the triangulation, in various parts of India, have been prepared, in duplicate, for the use of the Surveyor General's Office, and the Geographer to the Right Hon the Secretary of State for India The Photographic apparatus is also being usefully employed in copying and reducing Maps, and in furnishing preliminary copies for current use, until the originals are engraved and published Owing, however, to the small establishments at my disposal, the photography is necessarily restricted to the short period of the recess of the Kashmir party, three to four months, when the services of our best Photographer, Captain Melville, are available for their management

In the Instrumental Department, great advantages may be expected by the appointment recently made by the Right Hon the Secretary of State for India, of an Officer, Colonel Strange, to superintend the construction of the new Great Theodolite, and various astronomical instruments, which are being prepared in England for this Department When they are received in India, we shall be in a position to undertake the necessary operations for ascertaining our Longitudes, in connection with the Observatory at Greenwich, by means of the Electric Telegraph which is now brought across from the Mediterranean to India

J T WALKER

ANGLO-INDIAN ARCHITECTURE

THE revival of Architectural taste which has sprung up within the last twenty years in England, is slowly but gradually spreading to India, and within the last few years more than one handsome church, railway station, or other public building has been erected, which would do no discredit to any European capital This improvement has certainly not come before it was wanted Until very lately we did not shine in designing public or private buildings at home, witness the heterogeneous rows of suburban villas in the neighbourhood of London, or the unmitigated monotony and ugliness of many of our modern streets But we certainly surpassed ourselves in India, and succeeded in inventing a style of building, (irreverently known as the Military Board style,) which for ugliness beat everything that ever was constructed by man

Who does not know the sense of desolation that comes over one at first sight of some of our Indian cantonments, the straight and dusty roads, the rows of glaring white rectangular barracks, the barn-like church, differing only from a barrack in the presence of a square tower and classical (!) portico, the Roman Catholic chapel ditto, only smaller and with bright green doors all round

Then the houses, evidently built after the model of the barracks, unless when the genius of the builder had displayed itself in a profusion of bright colors on the external walls, arranged in such startling contrast that the dâk horses were very apt to shy at passing it.

If we go inside, matters are not much better. High bare white-washed walls, a barn-like roof, with perhaps a dirty ceiling cloth shaking in the wind, a dilapidated plaster floor and square holes cut in the wall doing duty as doors and windows. One exception

alone is there to this puritanical simplicity, in the fire-place, which is evidently an offspring of the genius of the native mason, and consists of a grotesque mass of ornaments which would perhaps be more effective if unblackened by the smoke from the ill-constructed chimney

The general reason assigned for such a state of things is—1st, The requirements of the climate, 2nd, The necessity of economy But the cogency of either argument must be altogether denied There can be no doubt that a thoroughly airy and well ventilated building may be made just as ornamental as one which is adapted for a cold climate only, and that a small amount of money expended in judicious ornamentation will scarcely affect the total cost of the building The real reason has been undoubtedly a want of taste and knowledge, and now that such deficiencies are beginning to disappear, it is hoped and believed that the beginning of an improved state of things has arrived It must I think, be allowed that the true principles of architectural construction for buildings in the East, which are to be used by men habituated to an entirely different climate, have not as yet been discovered, a Mosque, for instance, has a pleasant temperature both in winter and summer, while a Gothic Church in India is as a rule either very hot or very cold I do not say that Gothic Churches are unsuitable to India, but only that they are so as we now build them In the same way many of our houses with lofty rooms, numerous openings and thin walls, are far less cool and pleasant than native houses, low and badly ventilated as they are, with thick walls and few doorways I do not say that we ought to live in native houses, but simply that we have not as yet hit upon the right way of constructing our own.

Treating of Architecture as distinct from mere building, it is an art, not a science, and therefore does not fall under exact rules of instruction, one consequence, of which is, that while Engineering advances and improves, Architecture stands still and copies * We make better roads and bridges now than in the 15th century, but

* See a late article in the "Quarterly Review, "on the Progress of Engineering Science."

we have hardly got beyond copying their churches, and until there is a reformation in this respect, it is hopeless to expect that we shall have an Architecture adapted to the peculiar circumstances of Anglo-Indian It is not intended here to propound any original ideas on the subject of Anglo-Indian buildings, lay or ecclesiastical, but merely to offer a few hints for improvement in matters of detail which may be useful to those called upon to design and erect buildings in India

First, as to the style of our dwellings in the Upper Provinces As above hinted, it is doubted whether the present style is not radically unsuitable to the climate In a hot and damp country, especially if near the sea coast, numerous doors are certainly required by which the cool breezes may sweep through the house, and hence verandahs are necessary to shade the doors from the direct glare of the sun But where, as in Upper India, it is necessary during the fierce dry heat of April, May and June, to exclude the hot air altogether by night as well as by day, the fewer doors there are the better, and ventilation should be secured through the roof In the cold weather, the paucity of doors would add much to the comfort of the house, and verandahs might perhaps be altogether dispensed with The thin walls which now get so thoroughly baked that they continue to radiate heat by night and day for months together, should be made twice their present thickness, or better still, might be double Upper storied buildings are perhaps more suitable to Lower than Upper India, unless the upper rooms are used solely as dormitories, but considerations of expense will generally bar their adoption In many parts of the country perhaps the old Eastern style of building, round and open quadrangle in the centre might be adopted with advantage This open court paved with marble or stone, filled with fragrant shrubs, and with a fountain and tank in the centre, is characteristic of most of the dwellings of the wealthy throughout Syria and other Eastern countries, and is indeed common enough in native houses in India. Perhaps some one will work the idea into a tangible shape.

Next, let us protest against the indiscriminate use of plaster so generally applied to buildings of all kinds in India In most cases it is simply used to conceal bad masonry, and every plastered building looks shabby in a few months after being constructed It is expensive, and adds no strength to the work Brick masonry, if well executed, has a beauty of its own, and with well made bricks, well-bonded, and with fine joints, there can be no meaning whatever in hiding the material Some excellent specimens of brick masonry have been lately erected* in Upper India, but improvement is required in the manufacture of bricks before this kind of work can be executed to the best advantage, otherwise the dressing and chipping of the surface entails much labor and removes the outer skin of the brick, which is the most durable part, and is best fitted for resisting atmospheric effects The use of the pug-mill, a careful choice or mixture of earth, and perhaps the employment of machinery in moulding would ensure the requisite degree of excellence By the employment of colored bricks in the exterior mouldings very good ornamental effects might, it is believed, be produced Plaster must still be used for the interior surfaces of walls, and where the best kinds of lime plaster can be afforded, perhaps no better material can be wished than the smooth polished surface thereby produced But if inferior plaster be used, why daub it invariably with the lime whitewash, which comes off on the clothes and produces a most wretched and shabby effect? Wherever chalk can be obtained, it is little dearer than lime, looks much better, does not whiten your coat every time you lean against the wall, and takes the common coloring matters well Of these the *neila tutya*, (sulphate of copper,) the *peoree*, *soorukh*, and *Mooltanee muttee*, are well known in Upper India, and good shades of blue or green, yellow, red, and buff, are produced from them, but let them be mixed with chalk, not lime, as is usually done, and use a sizing of glue or rice water There is a popular but ill founded objection against the use of paper for walls In a damp climate like Bengal

* The new Government School-house at Umritsur, built by the Municipal Engineer, W. Gordon, Esq, and the new Lahore Railway Station, described in the present number, are excellent specimens

it would not do, but in the dry Upper Provinces there is no reason whatever for not employing it

Will somebody invent a new material for roofs in India? Slates we have not, except in one or two out of the way localities Galvanized iron we cannot get Tiles get broken and look ugly, and are leaky The ordinary flat terrace roofs leaks also, and is very heavy A trussed roof with a very slight pitch, (say 10°,) and covered with flat bricks and lime terrace is about the best we know, but is very far from being what it should be

But our floors are worse A lime floor looks very well when just finished, and for a private house answers its purpose fairly, but for a building like a barrack it is soon cut up, is unhealthy, (the dusty particles flying about engender opthalmia,) and impossible to repair satisfactorily A plank floor is expensive, perishable, and warps from the extreme change of the climate The best floors hitherto made are those of flat brick or brick-on-edge But why should not this method be improved upon in public and private buildings? Excellent colored and glazed tiles are made in the Punjab and other parts of India, and hexagonal or diamond shaped flooring tiles of white and blue or black look very well, and ought if properly made, to wear well The glaze is objectionable as making the floor slippery and apt to chip or wear off, but why should we not use the unglased encaustic tile now employed so largely in England by Minton and other manufacturers? No better floor could be devised for a private house in the hot weather than one of colored tiles, laid in an ornamental pattern, and which would enable us to dispense with carpet or matting I have little doubt that if a manufacture were started on a line of railway, the speculation would pay excellently, and I would recommend the idea to Government for the new public offices at Calcutta, Allahabad, and elsewhere. I believe the requisite materials exist in plenty throughout India, and nothing is wanted but the requisite skill and capital One other material may be named for floors, viz, gypsum or plaster of Paris, (sulphate of lime,) which abounds in some parts of India, as for instance, the Dehra Doon. It is excellently adapted for

floors, cornices, and other interior parts of buildings, and is capable of being made into highly ornamented forms

Fire-places and chimney-pieces must be left to the taste of the builder. The exceedingly ugly square upper windows may be replaced by circular ones, especially if the doors have circular fan-lights above them For both doors and windows colored glass may be used with great advantage to the comfort of the room, and the *diaphane*, or imitation stained glass, is both economical and pretty

Punkahs may be decidedly improved The kind generally known as the Bombay punkah, consisting of a single bar of wood with a heavy deep fringe, is decidedly superior to the abominable white-washed rectangle which invariably disfigures every room in Upper India But if the latter shape is preferred as giving more air, at least let it be colored or covered with ornamental paper, let the fringe be of good material and color, and above all, clean, and let the ugly thick white cotton ropes be replaced by thin colored cord or wire

Enough has been said for the present, or we might still declaim against mud walls of compounds, ugly rows of out-houses, hideously ornamental gateways, &c But as it is to be hoped a more refined taste is in progress, it may be sufficient to urge the subject on the attention of those whom it may concern

J. G M.

No. XX

THE LAHORE PASSENGER STATION—PUNJAB RAILWAY

Plan, Sections and Elevation are given of the above building, of which the Engraving presents a general view I have been disappointed in not receiving the Estimate and Sepecification

The Lahore Railway Terminus is about 400 yards distant from the Delhi Gate of the city, on the site of the old Sikh Cantonment of Naolucka, amongst the ruins of the ancient city Great difficulty and expense were incurred in getting in the foundations of the various Station buildings, owing to the depth of these ruins over the firm soil below

The buildings sanctioned, and either completed or in hand, are the Passenger Station, Goods' Shed, Workshops, Carriage Sheds and Locomotive Stables In designing the Passenger Station, it was thought advisable to give it a defensive character, as far as possible, and to arrange the defences so as to require but a small garrison Hence the Fort-like appearance of the present structure

The material employed is brick throughout, the outer surface being carefully dressed with very close joints It would be difficult to find better masonry anywhere The roofs are of pucka terrace on trusses of low pitch, except those over the platforms, which are to be of galvanized corrugated iron The floors are all of brick-on-edge, set very close, and dressed smooth The timber employed everywhere is deodar, from the forests of the Punjab Himalayas

The entrance archways at either end of the building can be closed when necessary by heavy sliding doors

The building was designed by Mr Wm Brunton, late, Chief Engineer of the Punjab Railway, and has been, I believe, chiefly executed under the superintendence of Mr E Baines, District Engineer, and the Architect of the Lahore Exhibition.

J G M

No XXI

BOAT AND PONTOON BRIDGES.

[Government having called for Reports on the best forms of Boats to be used in Boat bridges, and on the comparative merits of Boats and Pontoons, the following Reports were submitted by three of the officers consulted.]

From R. J CLARK, ESQUIRE, *Exec Engineer, 5th Division, Grand Trunk Road, to Superintending Engineer.*

Agra, 15th July, 1862

SIR,—In reply to letter from the Secretary to Government, N W Provinces, requiring a report on the best form of boats to be used in boat bridges, and also whether pontoons are not more suitable, and in the end more economical, I have the honor to state, that, if a bridge of boats was preferred, I should consider the following alterations required in a native boat to adapt it for bridge purposes

Instead of the broad flat bow of the native boat, the bow should be gradually rounded off from the straight side, by gradually bringing the side planks to meet at the stem, as by pointed bows the boats would offer less obstruction to the current, and cause less wear and tear in the moorings

Instead of the simple beams across the native boat, by which alone the sides are tied together and supported, I would have a series of strong frames across the boat, fitting, and secured to, the sides and bottom,

having one upright in the centre, and two sloping struts between the t(and bottom pieces, these frames would keep the boat in shape, and di tribute the weight of the roadway equally

I have noticed that in native boats, as now used, with the roa(way beams laid on the sides, or able to take a bearing on them, tl sides get all the weight, and usually bulge outwards, and as soon as tl boat has grounded, the bottom bulges upwards in the centre conside ably, also a heavy weight passing over the side of the boat causes gre undulation in the roadway

As to the fixing of the roadway, for the reasons above stated, I cons der that to make a roadway over boats as rigid as one over cylindric pontoons, the points of support for the roadway beams should be near as possible to the centre of the boat, this might be effected by longitudinal bearer notched down to the frames above-mentioned, in tl centre of the boat, and raised a little above the sides, to enable the bean to work clear of them, but this plan would increase the expense, long(beams being required

I beg to state, however, that in my opinion cylindrical pontoons a more suitable than boats for bridges, for the following reasons —

1st They offer, from their shape and size, less resistance to the cu rent than boats, and consequently, fewer moorings are required, boa fouling the bridge are more easily cleared, and the pontoon bridge is tl least liable to be carried away by sudden floods

2nd They are more secure against the weather, being entirely cove ed in, whereas boats require continual attention in the rains to keep the clear of water, and this would be against the durability of the boat compared with the pontoon

3rd I consider that there is less undulation in the roadway of a po toon bridge Pontoons being narrow, the bearing of the roadway bean is fromcentre to centre of the beams, or nearly so, and a weight passin over is supported at once by the whole buoyancy of the pontoon, where in boat bridges, as the roadways are, I believe usually laid, viz, with tw sets of working joints over each boat, a weight passing over must depre one side of a boat considerably before reaching its centre where the who buoyancy of the boat takes effect

4th Most bridges are partly made over a sand bank When the riv falls after the rains, the bed is frequently altered and the bridge settl

down on the sand unevenly, and with steep slopes in places If the bridge is on cylindrical pontoons it can be at once cheaply adjusted by digging the sand from under the pontoons without any carpenters's work Boats can only be lowered the same way at great expense, and then they are so imbedded in the sand as to be liable to be sunk by any sudden flood, or otherwise the roadway must be packed up, which involves expensive carpenter's work and hindrance to the traffic, the same adjustment is required at any change of the level of the water at other times This was found to be a continual source of expense when boats were used in the Agra bridge

5th As to durability, I have no means of ascertaining the difference between boats and pontoons in this respect, but the pontoon being more protected, ought to last the longest. The pontoon would stand, being placed on a dry sand bank for eight months in the year better than a boat. When the under side of a pontoon is nearly worn out, it might, with little expense, be reversed, and it would last nearly as long again

6th I am unable to state the comparative cost, but I imagine the cost of a boat or pontoon would be nearly equal The cost of a pontoon at Agra would run from 900 to 1,000 rupees, and I do not think a boat sufficiently large for bridge purposes could be obtained for less In some situations where wood could be obtained, cheap boats might perhaps be made cheapest, but I think that generally pontoons would be as cheap. They could be made quicker and are much easier to move about than boats

R J CLARK.

MEMO BY THE SUPERINTENDING ENGINEER

I think the Executive Engineer has submitted good reasons in the foregoing letter in favor of pontoons as compared with boats, to which may be added, that pontoons when built in compartments, must always be safer than boats of the ordinary kind, and cannot be burnt Such boats seem to have only the advantage of being more easily obtained when time is an object

With regard to cost, the market prices of the larger class of boats seem to vary from 600 to 1,000 rupees, according to size and locality, and there could not be much difference in the cost of a pontoon bridge of each kind.

Pontoons, moreover, can be more easily transported over roads, if occasion should require, either for commercial or military purposes, and iron, which is properly protected, will, I think, last longer than timber, with less leakage from alternate wet and dry conditions

J D CAMPBELL

From CAPTAIN D' LIMOND, R E, *Exec Engineer, Cawnpore Division, to Superintending Engineer*

Cawnpore, 1st September, 1862.

SIR,—I have the honor to acknowledge the receipt of your Memo, and to observe after due consideration, that I am of opinion pontoons are very much to be preferred

The boats at present in use, form an excellent bridge, with the strongest flood running, there is hardly any motion This of course arises from a great superabundance of buoyancy, entailing extra strain on the cables, and forming a great obstacle to the free passage of the current. I am afraid the existence of this bridge has had a great deal to say to the erosion of the bank up-stream, regarding which I have written you demi-officially

Long, narrow flat-bottomed boats, similar to English canal boats would not have this objection, but they are not free from the main one, which in my opinion most decidedly turns the scale in favor of the iron pontoon

The Ganges is in a very different state during the cold and hot seasons and the rains, there always must be tracts of sand to cross during the former seasons, I cannot explain on paper the difficulty and inconvenience during the period of transition If the boats are left aground they rapidly deteriorate, in short there are two periods of the year, the duration of each entirely dependent on the river, when it is impossible to keep the communication in a satisfactory condition, boats being used as the means of floatation If pontoons on the other hand be used, they can be allowed to ground, the roadway subsequently levelled by excavation of the sand below them, or, they can be rolled away with the greatest facility, and communication transferred to the

sand bank The removal of boats is not so easy, nor can such be done with the speed pontoons could be taken out Large pontoons with ten or twelve feet bays should be used, in preference to the smaller or military class

I had lately an opportunity of inspecting the pontoon bridge at Agra, the roadway is more level and superior to that on the Cawnpore bridge, for regular scantlings and means of floatation exactly similar, are used throughout its length

The pontoons are allowed to ground, but a level roadway is secured by excavating the sand beneath them

The course would not be so easy of execution with large boats, added to which iron pontoons do not apparently deteriorate by being left aground, while wooden boats certainly do At the same time, I beg to bring to notice that the cost of construction of such a bridge over the Ganges at Cawnpore would be as follows —

110 pontoons, with the superstructure, approximately, Rs 1,300 each, cost Rs 1,43,000, or in round numbers, one and half lacks of rupees

Cost of Boat Bridge

	Rs
Average number of boats during hot and cold seasons, 35, for eight months, at an average of Rs 35 per mensem,	9,800
Average number of boats during the rainy season, 60, at Rs 35 per mensem,	8,400
Average establishment for eight months, at Rs 300,	2,400
Average establishment for four months ,, 750,	3,000
Interest on Rs 31,000 expended on iron anchors, at four per cent,	1,240
Total Rupees,	24,840
To this add the cost of re-construction before the rains, the renewal of the down stream temporary anchors, the interest on the expenditure on superstructure, and it is feared that little will remain of the toll proceeds, viz, Rs 2,543-12 0 monthly, aggregating,	30,525
The risk of accidents remains	

D. Limond

From LIEUT J ECKFORD, R E, *Deputy Superintendent, Roorkee Workshops, to Superintendent General of Irrigation*

Roorkee, 30th July, 1862

SIR,—In reply to your letter, No 858, I beg to enclose a letter which I have received from Mr Campbell, whom I requested to inspect and report upon the Agra Pontoon Bridge There is no need for my informing you, what weight I should give to Mr Campbell's sense and practical judgment in a question like that which we have to consider, and I, too, would recommend the round pontoons for the following reasons —

We are asked by Colonel Morton to decide between boats and pontoons, I do not know exactly how to define the latter, or where the difference between the two commences, but in the discussion which took place on the first establishment of the British Pontoon equipage, the *open* boat was absolutely and totally condemned, though opinions varied as to whether the pontoon should be of a boat shape or the present service pattern, which is cylindrical We are now, however, treating of pontoons which are to be used for a very different object to military ones, and the arguments which apply to the latter will not hold as regards the former The shape and size of military pontoons are mainly fixed by their facility for carriage, facility in handling and launching, and facility for being rowed when the bridge is broken into rafts What we wish to arrive at is the cheapest form of pontoon adapted for a good permanent bridge for the heaviest traffic, taking into consideration that although the main part of the bridge may be permanent, the pontoon must be handy enough and with a sufficiently light draft of water to come quickly into place as the river rises, foot by foot, and submerges the low sandy ground, which generally covers a mile or two of its banks

The size of the pontoon must in great measure depend on the place it has to be used at, a very heavy pontoon might be used on the Jumna at Calpee where the river is one unbroken sheet, while at Cawnpore, where a low sandy island, full of creeks, intervenes between the Oudh and Doab banks, a lighter pattern must be adopted for the temporary parts This point must be determined mainly by the Executive Engineer, and from the long experience which the present Executive at Cawnpore has had, the question could not be in better hands

Wooden boats have only their cheapness in first cost to recommend them; wood is a peculiarly perishable material in India, and the boats

built are notoriously weak and frail Look at the superstructure of the Agra bridge, and think of an $8\frac{1}{2}$-inch square beam being rack-lashed down to the thin bulwark of an ordinary boat, while to build a good strong boat with proper knees, and her timber strongly fixed together, would in the present state of the timber market, and with such carpenters as are to be got, be dearer than cylindrical pontoons at Roorkee From actual experience on a bridge-of-boats, I can re-echo all Mr Campbell's objections to the Delhi bridge, the water falls rapidly and before the two or three boats, can be got out, (which form the small bridge over some creek,) the end of the creek has silted up, and the boats cannot be removed, they lie there to rot, their seams start from the heat, and the roadway over this part is lowered a foot or two which if not made of short kurries, tied to the boat with hemp lashings, would inevitably break the main beams Mr Campbell says that the Agra practice, where the men dig under the pontoon and let it deeper into the sand, and again pack it up when necessary, is perfectly successful in keeping a level roadway. You will see the difference between getting to the bottom of a 5 foot round pontoon, or to the bottom of a 15 feet beam flat-bottomed boat, (which is a small boat,) and this is one of the two main reasons in favor of the narrow cylindrical shape The applicability of this practice to Cawnpore should, I think, be first referred to the Executive Engineer there

Looking on iron then as the cheapest material, perhaps not at first, but certainly in the end, (Mr Campbell has not stated in his report, but has informed me that some of the pontoons have been in use for eighteen years,) the arguments for a boat-shaped pontoon are, her less resistance to the current from her fine bow entry, and that should the bridge ever be displaced you have a serviceable boat Neither of these reasons can for an instant be put in competition with those for a cylindrical one, namely, the superior facilities for keeping the bridge level, by being able to get underneath the pontoon, and its superior cheapness An iron boat has to have her sheets rivetted to angle iron framing, this framing is expensive and troublesome to set up, it requires careful workmen, and the constant supervision of the designer, while the curved plates of her bow and stern entries, require bending and rebending from unskilled natives, before they can be got to the proper curve

A cylindrical boiler on the other hand is about the most straight

forward work a man can do, every rivet of it can be given out to piece work, and it requires no inside framing, on these two reasons, therefore, of greater facility in keeping the bridge level, and a very great saving in prime cost, I would prefer the cylindrical shape

---

From A CAMPBELL, ESQ, *Special Assistant Engineer*, *to* LIEUTENANT ECKFORD, *Deputy Superintendent Canal Foundry, Roorkee*

SIR,—I beg, as requested by you, to report on the pontoon bridge at Agra, and also to state my own views on the subject of pontoons *versus* boats, for river bridges

The Agra bridge is supported on cylindrical sheet iron pontoons, the total length of the ordinary pontoons is 30 feet 8 inches, the middle part is 5 feet 8 inches in diameter, for a length of 22 feet The ends are egg-shaped, the thickness of the sheet iron is $\frac{3}{16}$-inch, and the sheets are rivetted together with $\frac{1}{2}$-inch rivets, spaced from 2 to $1\frac{3}{4}$ inches apart from centre to centre Each pontoon has a man hole, and a small hole for the mooring chain, the mooring chains vary, but are in general long linked chains $\frac{3}{4}$-inch diameter No anchors are used, their place being supplied with blocks of stone

The pontoons are spaced 18 feet apart from centre to centre, on the pontoons, and resting on a timber saddle, the longitudinal beams are placed, the two outside and the centre one being $8\frac{1}{2}$ inches square, with four intermediate ones $8\frac{1}{2}$ inches deep, by 5 inches broad, making in all seven beams, upon these beams, the planking consisting of one thickness of 3 inches sál is placed The width of this roadway or planking is 26 feet, it is spiked down to the longitudinal beams at each outside edge of planking Both above and below runs a longitudinal stringer of sál 7 inches wide by $2\frac{1}{2}$ inches thick, this is bolted together with wrought iron bolts, on the top of this, posts spaced 6 feet apart are stepped, between the posts run two lines of long linked $\frac{1}{4}$-inch chain Inside the pontoons are placed props of wood to stiffen the pontoons

To allow boats to pass up and down, there are two pontoons each four feet longer than the ordinary ones, on which are arranged two crabs with hinged platforms These are raised, the whole removed to one side, and returned when the boats have all passed The arrangement acts very well, but I think might be improved by the substitution of gearing, and winch handles, for the present handspike drum

The whole of the bridge was in good order, the undulations from the level were very slight, and everything seemed to be well looked after

I afterwards saw the bridge-of-boats at Delhi, and a more striking contrast could scarcely be imagined The road was a series of ups and downs, most of the boats were rotten, and had settled down in the sand till their bottoms had bulged up half way, a great number were so firmly fixed in the mud that in the event of a heavy flood coming, they would not rise, and, would, of course, be swamped, I believe that shortly before, 15 boats were carried away Some that I saw had their beams, to which the mooring rope was attached, half rotten through, while the ropes themselves were in many places covered with fungi, and looked in the same state

From the inspection, it was very evident that the road could not be kept so easily in line as a pontoon one, it was impossible to dig away the sand from under one of the large bottomed boats, some of the boats were very much up at the head and down at stern, owing to the earth under the stern being washed away, and the only means of partly rectifying it could be by raising the roadway Perhaps the great difference between the state of the two bridges is owing to the one being under the Executive Engineer of the roads, and the other under the Deputy Commissioner, but still I am firmly convinced that the pontoon bridge is in every respect superior to a bridge-of-boats for a permanent bridge over a large river

I have very few remarks to offer in regard to alterations from the present Agra bridge, but perhaps the substitution of iron beams for wooden ones would be an improvement in the end, as also I thing would be the laying down of broad plated tramways which would bind the planking together and prevent it from rising, and so get rid of the grass that makes the draught so heavy in wet weather The tramway would require to be of roughened plates to prevent the feet of the bullocks from slipping

If the pontoons were made in Roorkee, our price for each of the same size and thickness of iron, as the ones at Agra, would be Rs 800

Iron Pontoon Bridge for the Fyzabad and Allahabad Road, to be made up in the Roorkee Workshops Designed by A CAMPBELL, ESQ, C E, *Special Assistant Engineer*

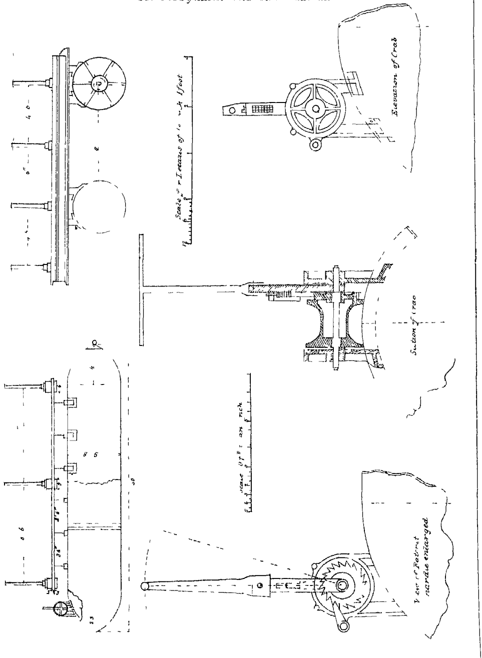
SPECIFICATION

Pontoons —To be of boiler plate $\frac{3}{16}$-inch thick, total length 30 feet,

BOAT AND PONTOON BRIDGES

Iron Pontoon Bridge

For the Fyzabad and Allahabad road



diameter, 5 feet 8 inches, parallel for 22 feet, the pontoon to be divided into three water-tight compartments by means of iron bulkheads The *bulkheads* to be of sheet iron $\frac{5}{16}$-inch thick At the upper end of pontoon, a *crab* with swinging barrel to be placed, the crab to be worked by means of ratchet and upright lever, something after the manner of a windlass on board-ship, the working handles will unship

Pontoon Brackets —Will be placed as shown in drawing, the girders will be bolted to these, and the brackets themselves bolted to the pontoons by six bolts

Girders —The girders for supporting roadway will be 18 feet long, 1 foot 2 inches deep the web $\frac{3}{16}$-inch thick, and the angle iron $2 \times 2 \times \frac{3}{8}$ inches, there will be six in the width of roadways

Anchors —Anchors and chains to be supplied, the chains to be $\frac{5}{8}$-inch diameter, and 80 feet long, to be BB short-link crane chain

Roadways —To be of 3-inch planking, bolted to the girders by $\frac{5}{8}$-inch bolts, and also fixed at centre and ends by stringers 3 inches thick, the roads to be guarded by angle iron standards with cast-iron shoes and two rows of long linked chain $\frac{5}{8}$-inch diameter, the chain to be fixed to the angle iron standards by means of bolts

Painting, &c —The pontoons and chains to be tarred, the other wrought and cast-iron work to receive two coats of the best oil paint

ESTIMATE

Detail	Quantity			Rate			Amount		
	M	S	C	RS	A	P	RS	A	P
36 Plates 6′ 0″ × 2′ 0″ × $\frac{5}{16}$,	40	20	0						
20 „ 4′ 0″ × 2′ 0″ × $\frac{5}{16}$,	15	0	0						
2 End Plates, 15″ dia × $\frac{3}{8}$″	0	23	0						
6 Plates 6′ 0″ × 2′ 0″ × $\frac{5}{16}$, bulkheads,	6	30	0						
	62	33	0	8	8	0	534	0	0
Rivets, 3156,	8	6	0	20	0	0	63	0	0
Punching holes, 6320,							13	12	0
Workmanship, including establishment,							200	0	0
Tarring,							4	3	3
Total for one Pontoon,							815	0	0
Bracket for fixing girder to Pontoon,	0	34	0	9	0	0	7	10	5
6 Bolts, $\frac{5}{8}$″ dia 2″ long,	0	1	6	42	0	0	1	7	1
Total for one Bracket,							9	1	6

Detail	Quantity			Rate			Amount		
	M	S	C	RS	A	P	RS	A	P
BEARING GIRDER, 18′ LONG × 1′ 2″ DEEP									
3 Plates, 6 × 1′ 2″ × $\frac{3}{16}$″,	2	0	0						
2 Strips, 10″ × 6″ × $\frac{1}{16}$″,	0	3	2						
	2	3	2	8	8	0	17	10	8
72 Feet of angle iron,	4	4	0	8	0	0	32	12	9
84 Rivets,	0	8	10	2	0	0	4	5	0
250 Rivet holes,							0	8	9
Workmanship,							5	4	0
Total for one Girder,							60	9	2
RAILING STANDARD									
4 Feet of 2″ × 2″ × ¼″ angle iron,	0	6	0	8	0	0	1	3	4
Cast iron shoe,	0	6	0	9	0	0	1	5	8
4 Bolts ½″ dia 10½″ long, ogee nuts,	0	1	7	28	0	0	1	0	0
2 Bolts ½″ dia 1½″ long, and nuts,	0	12	0	40	0	0	0	12	0
Total for one Standard,							4	5	0
BOW AND STERN. CRABS									
2 Crab cheeks,	2	10	0				23	4	0
1 Barrel,	2	4	0				21	6	6
1 Barrel spindle,	0	12	8				7	14	0
1 Pin for pall,	0	3	8				5	6	0
1 Pall,	0	2	3				3	3	9
2 Distance bolts, ¾″,	0	3	8				4	6	0
1 Lever,	0	17	0				11	9	8
1 Pall pieces,	0	2	6				2	11	9
8 Bolts for fixing do 1″ dia 3′ long,	7	0	0				4	6	0
Fitting up and fixing,							5	12	4
Total for one set of Crabs,							90	0	0
Pattern, painting, &c,							2	0	0
Handle for crabs,	0	16	0	20	0	0	8	0	0
⅜″ Chain for pontoon, 80 feet,	1	32	0	22	0	0	40	0	0

ABSTRACT

	Detail	Quantity			Rate			Amount		
		M	S	C	Rs	A	P	Rs	A	P
66	Pontoons, each,				815	0	0	53,790	0	0
66	Set of brackets with bolts for do, each set,				108	0	0	7,128	0	0
66	Crabs, with fixing bolts, each,				90	0	0	5,940	0	0
66	Anchors, each,				20	0	0	1,320	0	0
66	Anchor chains, 80 feet long, $\frac{5}{8}''$ each,				40	0	0	2,640	0	0
402	Girders, 18 feet long,				62	0	0	24,924	0	0
804	Standards for chains, with fixing bolts,				4	5	0	3,467	4	0
6	Chains, 1,200 feet long, each,				500	0	0	3,000	0	0
800	Bolts, $\frac{5}{8}''$ diameter, 10″ long, for stringers, per maund,	11	20	0	20	0	0	230	3	4
3200	Do $\frac{3}{8}''$ do 4″ long for planking, per maund,	7	20	0	25	0	0	187	8	0
800	Washers for $\frac{5}{8}''$ bolts, each,				0	0	3	12	8	0
6	Handles for working crabs, each,				10	0	0	60	0	0
	Bilge pumps, each,				30	0	0	390	0	0
	Total Iron work in Bridge,							1,08,089	7	4

No XXII

ABBOTTABAD CHURCH—PUNJAB

Designed and Constructed by LIEUT BLAIR, R E, *Executive Engineer, Hazara.*

REPORT

THE Church is to be built in a palisaded ravelin on the western front of the proposed new fort at Abbottabad, on the side of the old Kutcherry

The Church will be built for 150 sittings, and in the early English style of architecture

The cost to be Rs 15,000, of which the Government grant is 10,000, and the remaining 5,000, have been guaranteed by the Local Committee

The enclosed design has 1,350 superficial feet for sitting, or allows 9 superficial feet per sitting

As no sandstone is obtainable in this district, the cornices and other decorations will be plain but massive, throwing deep shadows, for as the Church will have to be built with the hard blue lime stone from the Abbottabad quarry, so for economy sake the decorations have to be simple

The Church is to be built in the most substantial manner, and will be roofed with a high pitch shingle roof, as this style of roofing is found to be best adapted for this district.

To harmonize with the mountain scenery a wooden spire has been included as a set off to the northern face of this design

The interior will be plastered with gray plaster in imitation of stone, and will have a high open roof with decorated trusses and furnished

with handsome sittings with poppy head decorations, pulpit, altar table, &c, of walnut wood

The rates in this estimate may appear high but are intended to cover the cost of furnishing all portions of the building, with the very best description of workmanship and materials, and it is solely for this purpose that private subscriptions have been given

---

SPECIFICATION

The space for 200 feet square to be levelled and to be spread with 6 inches of gravel

Foundation and plinth to be of hammer-dressed pucka rubble masonry, with best lime cement of equal parts of lime, sand, and soorkhee

The superstructure including cornices, mullions, and all exterior work, will be of neatly cut stone dressed on all six sides and set in the best cement of equal parts of lime, sand, and soorkhee, well ground in a mill

The interior will be plastered with polished gray chunam, plaster colored gray with a slight mixture of charcoal, but the cornices and corbels will be left white.

The doors and windows to be made of walnut wood, the former of double (diagonally) 1-inch planking, strengthened with decorated iron hinges and the windows to be on 6 inches diamond shape framework, glazed with ground glass

The roof to be of treble shingles of deodar wood, 2 feet 6 × 6 inches × 2 inches, laid on 2 inches horizontal planking, having a ridge piece decorated with poppy heads.

The trusses to be 6 feet 3 inches from centre to centre, of deodar wood of timbers 9 × 6 inches, with lower edges bevelled and decorated, to consist of principals, collar beam, two braces, and an arched brace, with pendant resting on an ornamental corbel, the principals and pendants are fixed to a hammer beam to give the trusses a fair bearing in the wall, the whole truss will be braced together with ornamented iron straps and bolts

The floors of the Church to be of one layer of dressed stone on well rammed earth with 4 inches of well beaten and polished terrace plaster

Spire—The roof of the spire to be of double 1-inch grooved planking, supported on a square shaped truss, the octagonal shape being given by the purlins, which are 12 × 3 inches, and let in sideways into the principals

The main truss to consist of four principals, 6 × 6 inches at the top, and 12 × 10 inches at the base, with six collar beams, and diagonal bracing of 6 × 6 inches timbers

The principals fit into an iron cap at the top, and are firmly set into massive tie-beams, 12 × 10 inches at the base, besides which to give them greater stability, they will be braced to the flooring beams of the two lower stories, with double beams 10 × 4 inches at each corner, and at the joint with the tie-beam, strong iron knees will be given

The sittings to be 9 feet long for 5 sittings, of walnut wood, with solid 1½ inch plank sides, decorated

The altar, pulpit, and altar rails to be of walnut wood, highly decorated, and supplied with cushions of English embroidered crimson cloth.

ABSTRACT

80,000	Cubic feet earthwork, at Rs 3 per 1,000, -	240 0 0	
9,566	Cubic feet foundation, at Rs 12 per 100, -	1,148 0 0	
20,572	Cubic feet superstructure with arching and cornice work, at Rs 23 per 100, -	4,732 0 0	
6,231	Pucka gray plaster, at Rs 71 per 100, -	436 0 0	
or 30,138	Cubic feet masonry, at Rs 21-12, about, -		6,556 0 0
1,827	Pucka flooring, at Rs. 10 per 100, -		183 0 0
636	Doors and windows, at Rs 2-12 per foot, -		1,733 0 0
5,599	Shingle roofing, at Rs 24 per 100, -	1,344 0 0	
902	Timber work, at Rs 2-8 per foot, -	2,255 0 0	
40	Maunds iron work, including lightning conductor, at Rs 20, - - -	800 0 0	
or 5,599	Roofing with spire and scaffolding, at Rs 78-6, nearly, - - - -		4,399 0 0
	FITTINGS.		
150	Seats, at Rs 6 each,- - - -	900 0 0	
1	Pulpit and altar, - - - -	240 0 0	
1	Font, - - - - -	100 0 0	
	Altar rails and chairs, - - -	100 0 0	1,340 0 0
	Total, -		14,211 0 0
	Contingencies, - -		711 0 0
	Grand Total, -		14,922 0 0

H. BLAIR, LIEUT., R.E.,
Exec Engineer, Hazara Division.

No XXIII

SIND CANAL REGULATORS

Memorandum descriptive of a Regulator proposed for large Canals in Sind By LIEUT -COLONEL FIFE, R E

ONE of the most serious difficulties the Engineer encounters in the management of Canals in Sind, arises from the enormous quantity of silt which enters from the rivers In the case of the simple Inundation Canals of the country, the silt can be removed by manual labor when the water subsides at the conclusion of the season, though, of course, this annual operation adds enormously to the cost of maintenance But with respect to Perennial Canals, where navigation, as well as irrigation, has to be maintained throughout the year, the difficulty is more serious It is true that the nicely adjusted gradient of the Canal, designed by the skilful Engineer of the present day, and the constancy of the stream, permit much less silt to accumulate than must take place in the Inundation Canal, with its ever varying velocity of current, and much of the matter which is now deposited in the bed of the Inundation Canal will be swept into the smallest distributing channels, and even into the fields, by means of the Perennial Canal But still there is a large quantity of sand borne along by the waters of the Indus which must either be removed from time to time, or prevented from entering the Perennial Canal at all

The subject of silt traps has often been discussed, and that such an arrangement is feasible needs no demonstration An extra depth to the Canal at its head, sufficient to slacken the velocity of the current, till it allows the heavier particles of sand, but not the finer particles

and the mud, to be deposited, is all that is required There will be considerable expense in clearing this from time to time, and perhaps some slight inconvenience, but the difficulty may be said to be reduced to an item of annual expense, by means of the silt trap Dredging may be resorted to, and when the works are on a very large scale, the dredging machine might be employed with advantage, as it was many years ago on the Caledonian Canal, where it was found cheaper to let the sand in a cutting fall down to the level of the bottom of the Canal and afterwards to take it up with the dredging machine than to remove it in the ordinary manner from above The dredging machine in the instance I have alluded to, cut its way through the ground and formed the Canal Whatever arrangement is made for removing the silt, however, the trap may be said to reduce the silt difficulty to an item of annual expense

But this annual expense will be considerable, and to prevent the heavy silt entering the Canal at all would therefore be more satisfactory, and with this view I proposed for one of the large Sind Canals the construction of an escape channel, or artificial branch of the river, and the drawing off of the Canals supply from the escape channel, and not direct from the river in its silt loaded condition The stream in the escape channel was to be regulated to such a velocity that the heavy silt might be thrown down into the bed and rolled onwards back to the river again, the Canal receiving its supply from the top or surface water after the heavy silt had sunk to the bottom. *Fig* 1, exemplifies the arrangement described It should be understood that there is a fall in the river's surface of about $2\frac{1}{2}$ feet between the mouth and tail of the escape channel

For the purpose of obtaining the Canal supply from the top water and to secure facility in working the sluices, security against accident, and permanency of construction, I proposed making the gates in three pieces (the principle of the Ganges Canal gates) to be worked singly or together as occasion might require, the whole, including guides, to be of iron This construction will be expensive in the first instance, but its permanency and facility of working will render it perhaps not more expensive than the wooden gates in use, while I believe there are other advantages which will render it very superior to the wooden gates

SIND CANAL REGULATORS

Proposed Regulating Bridge at Rori

Fig 2

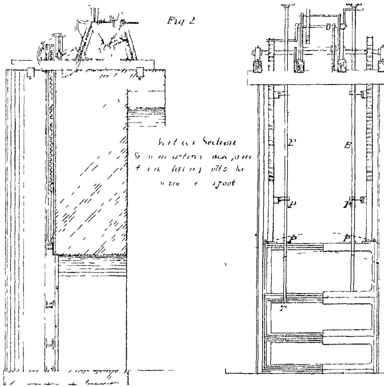
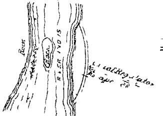
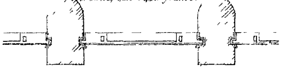


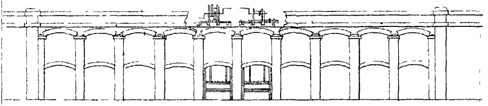
Fig 1



Plan
Showing gates & gate frames



General Elevation



A drawing, *Fig* 2, of one of the gates is attached The opening to be regulated is 10 feet square, and there are to be 10 in number The greatest depth of water outside the regulator is to be 21 feet The pieces of the gate are composed of iron frames, with ⅝-inch plates over them The connecting or disconnecting of the three pieces composing each gate is to be effected by means of two bars BB, passing through eyes attached to the different pieces and with T heads and cross pieces, PP The connecting or disconnecting is effected by sliding these bars up or down, and then giving them a half turn to either lock or unlock the T heads and cross pieces in the eyes The handle at the top is parallel to the T head at bottom, and it can always therefore be seen whether the pieces of the gate are locked together or unlocked

During floods the top piece of the gate only would be worked. When the raising of this piece is insufficient to supply the required quantity of water, the second piece is to be attached and drawn up also When a still larger aperture is wanted the whole of the pieces are to be taken up It will, however, only be necessary to lift the whole gate when the Indus is at its lowest level, and when there would be comparatively speaking but little heavy silt in motion outside the regulator, or even at the mouth of the escape channel

The raising and lowering of the gates is to be effected by two four-ton winches The greatest force even required by theory for weight and friction combined, is about 3¾ tons In this case the river would be standing at 21 feet outside the regulator and the Canal would be empty The top piece of the gate only would be raised

A very serious inconvenience in the management of regulators in Sind arises from the enormous quantities of drift trees, bushes, and grass The trees if large must remain against the regulator, if they should ever be drawn into the Canal entrance, till they can be cut up or withdrawn by means of ropes, but in the daily working of the Naira river regulator, we found the grasses a more serious inconvenience than any thing else These twist round wood-work in such quantities as to render it immoveable I believe that the iron gate with its sharp edges and tremendous weight would destroy all these minor obstacles without difficulty By alternately raising and lowering the gate very slightly it would cut through grass and break up

bushes and branches till they become small enough to pass through the orifice.

I have a plan on a large scale of these gates, and should the construction suit other Canal works, I shall be happy to send a copy to any officer who may wish for one. I have some confidence as to the gates working well in practice, as I consulted a very able engineer, (Mr. Hoskins, the Directing Engineer to some large iron works on the river Lyne,) who assisted me in the details. I was informed that such gates, with winches complete, would probably cost £2 or £2 10*s* per square foot of opening. At this rate each gate 10 + 10 feet would cost £200 or £250.

The subject of the size of openings appears to me to demand some discussion. I have fixed the size in the case given at 10 feet, as it appeared to me convenient as respects the weight of the gates and the power requisite to move them. Each gate with its rack bars and connecting rods will weigh about 3¾ tons. The strength is much greater than would be given to a dock gate, in order that there may be less likelihood of accident from any thing striking against them. Small openings in a regulator possess the advantage of very easy working, but the additional masonry piers required, add greatly to the cost, and the flow of the stream is impeded. The advantage of the very small opening however vanishes altogether, when it is necessary to make the covering plates and the framing as secure against a blow from a drift tree or branch as they are in a large gate. The covering plate *must* be thick, hence we cannot calculate on saving material by using very small gates, while the increase in the number of winches for a larger number of small openings would add to the cost.

A large opening possesses one great advantage over a small one, if it can only be kept under command. It affords greater facility for getting rid of obstacles brought down by the river. I will conclude by venturing the suggestion that openings should be as large as possible consistent with the easy working of the gates. Those I have proposed are 10 feet by 10 feet, but more able and experienced engineers than myself may be able to show an advantage in making them much larger.

J. G. FIFE.

No XXIV

STRIKING BRIDGE CENTRES.

[The following letters refer to the method of Striking Centres adopted by Captain Mead, in the Moirhui Bridge, which was described in No II. of the "Professional Papers."]

From the Superintending Engineer, Southern Division, Bombay

Poona, 1st January, 1864

THE Superintending Engineer has the honor to forward reports from the Executive Engineers, Belgaum and Dharwar, on the methods they are now employing for striking centerings of large bridges, as called for by Government

Both Captain Merriman and Mr Hart object to the use of sand bags as not possessing sufficient strength, and owing to the settlement which takes place consequent on the alteration of their form when subjected to heavy weight; and both these officers have now adopted sand *boxes*, which doubtless possess the advantage over sand *bags*, noted by Captain Merriman in his report

Although Mr Hart has hitherto used wooden boxes as being cheaper than iron, he gives the preference to *iron* boxes, and although Captain Merriman has fitted his cylinders with wooden plungers, he now agrees with the undersigned that the latter, if made of iron, would be an improvement Lieut.-Colonel Scott thinks it would be a further improvement to allow the sand to escape from *below*, instead of from the sides, of the cylinders, when one hole instead of four would suffice, and the sand

would run out with greater regularity The cost also of making the cylinders would be considerably diminished

The Superintending Engineer, is aware that the sand boxes as originally invented by M Bandemonlin, said to have been perfected by M de Lazilly, and now used in England, are exactly similar in principle to those prepared by Captain Merriman, but if time and cost can be economised by a more simple arrangement something is gained

C SCOTT, LIEUT -COLONEL, R E,
Superintending Engineer, S D

To the Superintending Engineer, Southern Division

Belgaum, 9th November, 1863

SIR,—I send a drawing showing the arrangements I mean to adopt for striking the centres of bridges on the Belgaum and Kolapoor road, and in the course of a couple of months, I shall have an opportunity of reporting on the same

I feel confident that success will attend this arrangement, for in one case last season, when I used sand in bags only, there was no failure, though the centres had to be supported with blocks before the key stone was driven, owing to the bags having commenced to split from the weight brought upon them during the construction of the arch. In fact, I had to adopt the method used by Captain Mead while the work was in progress, instead of from the commencement The blocks were eventually knocked away and the centre lowered by opening the mouths of the sand bags

By having the sand in iron cylinders from the commencement, this double process will not be necessary The only doubt is whether the sand will run out freely on the doors being opened if it happens to have got into a moist state, but I see no reason why it should not be kept perfectly dry, for the timber piston or plunger fits close into the iron cylinder, which might moreover be temporarily covered so as to prevent any moisture finding its way between the piston and the cylinder.

It will be observed that there are two sets of sliding doors in those cylinders so that the centers may be lowered by degrees, and with more regularity than with sand bags The doors can moreover be opened and closed at pleasure with the greatest ease.

Of course these cylinders are expensive, but they will last for ever when once made up, and their cost can be recovered by charging a small sum for each upon each bridge used

I do not think I would ever again trust to sand bags alone to support a centre for an arch in progress I would only use them for the actual operation of striking as in the case reported by Captain Mead

C J MERRIMAN, CAPT , R E ,
Exec Engineer, Belgaum and Kolapoor

To the Superintending Engineer, Southern Division

Dharwar, 21st November, 1863

In 1857, when Colonel Kennedy's assistant in Sattara, he suggested to me the use of sand bags as noticed in Weale's " Treatise on Bridges " On the Koombarle Ghaut road, when an opportunity presented itself, I carried out his suggestion in the case of a bridge of 40 feet span, and found the method to be both satisfactory and economical

I submitted a report at the time to Colonel Kennedy

The next opportunity I had of using them was on the Whagaray bridge at Nassick, and I mentioned the circumstance in my annual report for the year 1860-61

The great advantage obtained by the use of sand bags, I found to be—saving of expense and simplicity of arrangement, together with diminution of danger to the work and workmen, at the time of striking the centres

Masonry arches are tried very seriously by the jar produced when wedges suddenly fly home and sometimes actual injury is produced Again, the heavy pressure of the superincumbent load locks the fibres of the wood forming them, so firmly together, that no force will start them, and I have seen a wedge broken to pieces with a sledge hammer which it had been necessary to use to drive it Last year two wedges had to be cut out from under the centres of a 30 feet arch, so immoveable had they become, whereas the motion of the centres under the use of sand bags is so gradual, that the eye can scarcely note the settlement of the frames, till the increasing space over the laggings shows that the structure is slowly descending

There is little or no pressure from the sand trying to escape, and the mouths of the bags can be closed without trouble

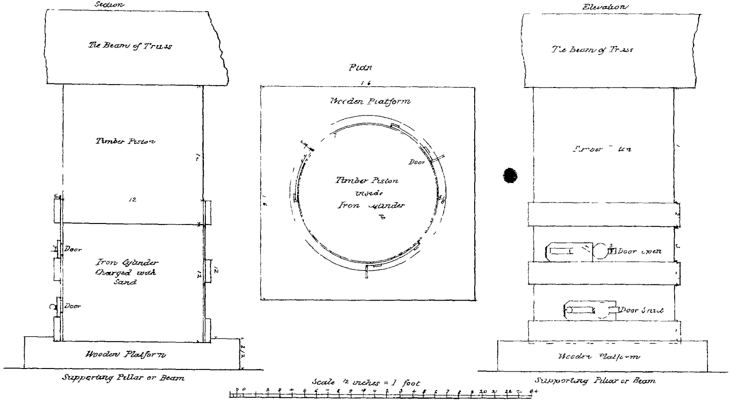
I do not describe the construction of the sand bags, because I have come to the conclusion that boxes are very much preferable to bags in practice; and I have had them made up for use in the bridges now under construction in these districts, and found them to act well

The disadvantages of bags are the possibility of their bursting, either from decay, or from the attacks of white-ants There is also a slight settlement which takes place as the load comes on them, this is due I believe to the stretching of the cloth and the alteration of form, through flattening of the bag It was always necessary to provide for this, and for accidents, by placing a block of wood between the horizontal beams to relieve the bags of the pressure of the centre till it became necessary to use them These blocks were easily removed

Cast-iron cylinders have been used in England lately, and Captain Merriman has had several of wrought-iron made up in Belgaum, and will doubtless describe their construction It is not always possible to get iron ones constructed, I therefore send you a sketch of the wooden sand boxes I have had made up, but the iron cylinders being much preferable, I would recommend their adoption by any one who can get such easily

JOHN H E HART,
Exec. Engineer, Dharwar Division

STRIKING BRIDGE CENTRES



No XXV

KOHAT FORT—PUNJAB

From LIEUT A W GARNETT, *Exec. Engineer, Kohat, to Superintending Engineer, Lahore*

Hungoo, 17th September, 1855

SIR,—The documents which accompany this Report, are as follows —

I Revised estimate of the cost of restoring the Fort of Kohat, with Appendices

II Statement of the armament and stores required for the defence of the several works

To illustrate the above I forward a general plan of the Fort and environs, as they will appear on completion of the works

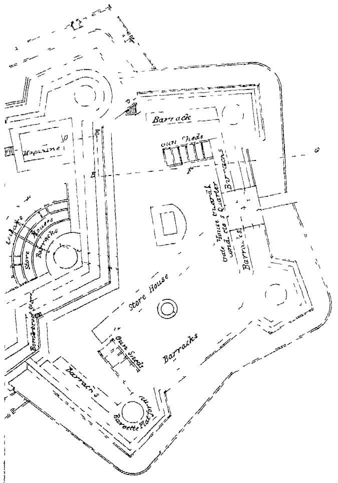
To save the trouble of reference to former correspondence, I shall first give a brief retrospect of past operations, after which, I propose to notice the several departures from the original design, which have been found necessary, and the several improvements and additions that have been subsequently recommended, and shall conclude my report by explaining the effect of the above on the quantities and rates of the estimate I have now the honor to submit

The defences of Kohat first claimed the attention of the Government, immediately after the annexation of the Punjab, and I undertook some repairs to the old works in 1850, by order of the late Board of Administration During these operations the old walls were found to be in such a state of decay, that no mere patching up could preserve them, and the attempt was abandoned by orders of the Board in April 1851,

Nothing further was done till March in the following year. In that month, I was called on for an estimate of the probable cost of putting the old Fort in a state of defence. My designs comprised the restoration of the ramparts of the old Fort, and a masonry revetment to the escarp slope of its ditch, the addition of a crown work on its steep south side, and the removal of those portions of the town within 350 yards of the works, also some improvements in the Cantonments. The Government sanctioned an expenditure of Rs 81,639-3-3, on my rough estimate of the probable cost of the above works, and operations were commenced on the 1st December, 1852. The progress was slow at first, hands were scarce, and all materials had to be prepared on the spot, before masonry works could be undertaken. On the 13th October, in the following year, the Government sanctioned the importation of laborers at high rates of pay, which gave me the command of as many hands as I could employ with advantage. Earlier in the same year, Ensign Basevi's services were placed at my disposal for the supervision of the Fort works. By the end of 1853, not less than 1,000 men were employed daily on the Fort, and with the exception of temporary interruptions from rains, nothing occurred afterwards to retard the progress of the works. On the 20th February, 1854, I reported the injuries sustained by the heavy rains which fell in that month. Also the loss of the whole western face and the north-west bastion of the Upper Fort (the eastern face with its two bastions had been previously destroyed by a severe earthquake, which occurred on the 30th July, 1853). On the 25th of May following, the modifications of my original plans, which I considered necessary, and their effect on the cost of the works were explained in my report of that date. The subsequent progress of the works has been fully described from month to month, and rough drawings have been supplied to show the actual state of the Fort at particular periods. All operations were suspended, agreeably to order, on the 1st July, 1855, and on the same date, I reported the several works which still remained to be completed.

I have alluded to certain departures from the original designs, which I shall now proceed to explain. They are of three kinds—First, Modifications in construction, rendered necessary by difficulties which could not be altogether foreseen or provided for in the rough estimate, Second, Alterations in design, consequent upon occurrences during the progress of the work, which could not have been previously calculated upon, Third

THE FORT OF KOHAT



Additions to meet extra requirements not provided for in the original estimate.

The modifications in construction have been chiefly confined to the foundations of the escarp revetments, and buildings in the Upper Fort. The foundation works were in progress during the Chief Commissioner's inspection in April, 1854, so their nature will no doubt be in his recollection. The arches which support the superstructure of the scarp revetment, are turned on forty eight piers of masonry, of an average depth of 18 feet, whilst some of them were nearly double this depth. The magazine in the Upper Fort will rest on similar foundations. No provision was made in the rough estimate for works of this description. It has also been found necessary to substitute pucka masonry retaining walls for kucha ones, at the junction of the Lower Fort ramparts with the Upper Fort rownee, on account of the great height and weight of the ramparts at these points. I may also here mention that "rubble masonry," has been substituted for "brick masonry" in some cases, to effect a saving in the latter material, and that either "kucha brick" or "kucha rubble" has been substituted for the "mud work" of the original estimate, the former in all exterior walls of ramparts, the latter in all interior walls. The "mud work" was partially employed in the Lower Fort ramparts, but it was found to be impracticable to build these walls entirely of mud.

The alterations in design have been chiefly connected with the "relief" of the Upper Fort. The original designs were of course influenced by the existing walls, for the preservation of which they were adapted, but when these walls all disappeared one after another, until nothing was left but the old mound on which they stood, there was no longer the same necessity for carrying up the new "revetments" to such a height. It was too late to alter the plan of them, as the foundations had been partly laid in, but a great improvement was effected by reducing their height, and the height of the whole of the Upper Fort by about 10 feet. Of other alterations, may be named the omission of a fifth bastion, at the angle of the Upper Fort, enclosed in the crown work, and some improvements in the tracing of the galleries.

The additional works to meet extra requirements are the buildings for the Ordnance Department, including quarters for a Conductor, storehouses, and gun-sheds. The interior space in the Fort is so confined, that it is not easy to provide the requisite amount of accommodation for stores of all

descriptions By the arrangements shown in the drawings, I shall secure the following amount of flooring in the different buildings —

UPPER FORT

Bomb proof buildings,	780 superficial feet	
Storehouses,	10,295	"
Cellars,	3,960	"

LOWER FORT

Bomb proofs,	160 superficial feet	
Storehouses,	2 640	"
Gun sheds,	2,376	"

The following are the chief additional improvements which are recommended to complete the defences —

1st A "covered way" is required to the west, north, and east fronts of the Upper Fort The object of this work is to cover the scarp wall which is now much exposed to view from without, it has also other uses The glacis of the Upper Fort will be somewhat steeper with this addition, and it will be necessary to turf it or to sow its slopes with grass This has been provided for in the estimate

2nd The parapets are required to be increased to 10 feet in thickness, in both the Upper and Lower Fort Where the walls are not yet built, as on the two south fronts of the Upper Fort, the necessary thickness will be given to the ramparts to admit of a 10 feet parapet, but in other parts the extra thickness must be given by building out on the terreplein or space left for the passage of the defenders along the ramparts, and the roofs of the Barracks along the interior wall must be raised and strengthened sufficiently to serve as a passage for guns round the Fort

3rd The magazine in the Upper Fort will be built in the manner suggested by Col Napier, during his inspection last spring, *i e*, with its floor sunk below the level of the Upper Fort But with regard to this building, it appears that it will not afford the room now required by the Commissary of Ordnance I propose giving the additional space required, by converting a passage in the townee of the Upper Fort into an auxiliary magazine This passage was originally intended as part of a postern to communicate with the interior of the Upper Fort, but will

be superseded by a more direct and safer communication, to be alluded to presently It is situated in a part of the rownee inclosed in the Lower Fort, in a position very little exposed, and can be rendered bomb-proof easily

4th The "postern" leading from the interior of the Lower Fort direct to the interior of the Upper, is a work so much needed, that it should be rather looked on as an omission in the former designs than as any addition to them

5th A new entrance in the north front of the Upper Fort, with a bridge and "place of arms," has been provided for in the estimate The counterscarp or outer wall of the ditch being here 10 feet lower than the rownee, it will be necessary to enter the latter by a postern and steps

6th The completion of the masonry revetment, with rownee, &c , round the two south fronts of the Upper Fort has been included in the estimate The objects, and I may add the necessity, of this work are sufficiently obvious

7th It is proposed to reduce the height of the mound and rock to the north of the Fort, so as to bring it as much as possible under the fire of the Upper Fort This will be explained by the sections

Lastly The remaining improvements proposed require no remarks, as their uses are obvious The following have been provided for in the revised estimate —

Bomb-proof coverings to wells

A caponniere to communicate between the Upper Fort and the out work to the north.

A masonry "traverse" to protect the entrance to the Lower Fort, which will also serve as an expense magazine for the Lower Fort

Barbette platforms in the bastions

The great difference between the quantities of work executed, and those estimated for, is partly attributable to the modifications in construction explained before, but more particularly to former omissions There is a wide difference between estimating for an original design and estimating for the restoration of a tottering old Fort In the one case the measurements are certain, however inadequate the rates may be In the other they are uncertain, *i e*, they depend upon contingencies which no amount of experience can always anticipate I have explained how the measurements have been largely affected, in one instance, by the great depths to

which it was found necessary to penetrate for foundations, how walls which it was intended to retain disappeared altogether during the progress of the work, and had to be replaced *de novo,* and how bastions have crumbled away before the protective masonry walls could be built to support them. I may mention in addition, that the adaptation of the new works to the remains of the old Fort, have not only been attended by difficulties, but by considerable danger to the people employed. As to the cost of works, the Government will have been prepared to expect a considerable increase in the charges when sanctioning the advance in the rates of payments, to secure a large supply of laborers. But there are other causes which have tended to make the Fort works more expensive. The confined space in which the bulk of the operations was carried on, the great heights at which some of the works, and the great depths at which others were executed, the losses by rains in this variable climate, not so much by the injuries done to the works as by the interruptions they occasioned, whilst the work people were receiving an uniform monthly pay, were another source of expense. A single day's rain would thus cost Rs 300, exclusive of the cost of repairing damages. I am aware these are contingences usually supposed to be covered by a small per centage on the amount of the estimate, but instead of adding a twentieth to the cost, they increase it a fifth or thereabouts, in a work like the Fort of Kohat.

With the above observations, I now submit the final estimate for this work, amounting to Rs 4,06,012-6-7. I ask this sum to complete the defences of Kohat. It includes the cost of all works executed up to the present time, and all additions and improvements that have been recommended, but does not include the cost of alterations in the Cantonments, which should not be confounded with the defensive works, as in the original estimate, and it does not include the cost of ordnance and stores required to maintain the Fort in a defensible state.

A. W. GARNETT

Statement of Armament and Ordnance Stores required for the Fort of Kohat *

Ordnance		
Ordnance, iron gun, garrison, 18 pounder,		6
" " " " 9 pounder,		10
" " mortar, 8-inch,		8
Ordnance Stores		
Axletrees, iron, siege carriage, N P, spare,		2
Barrels, bouge,		8
Bars, lifting, gun carriage,		2
Beds, mortar iron, 8 inch,		9
Blinds, embrasure,		
Blocks, iron, with B sheaves, double, large,		2
" " " single "		2
Blue lights,		80
Boilers, copper, medium and small,		2
" iron, " "		2
Borax,	lbs,	
Boxes for implements, guns,		8
" ammunition, tar and grease,		4
" case shot, 18-pounder,		In proportion to stores
" fuze,		
" light balls,		
" signal rockets,		
" naves, brass, for siege carriages, spare,		4
Brass or gun metal, hammered,	lbs,	60
Brushes, painting, large and small,		6
Buckets, wooden, gun,		8
Carriages, garrison, iron, 18-pounder,		4
" " wooden, 18 pounder,		4
" " iron, 9-pounder,		6
" " wooden 9-pounder,		6
" siege, limber, with ES 18-pounder, N P,		3
" " " " 9-pounder,		5
" garrison, wooden, depression, 18-pounder,		2
" " " " 9-pounder,		2
" cart, hand or truck,		2
" transport,		1
Cartridges, siege, empty gun, 18 pounder,		3,600
" " " " 9 pounder,		6,000
Chains, draft, siege, carriage, leading,		8
" " " " pole,		8
" transport carriage,		1
" for drag ropes, siege,		16
" locking siege carriage,		8
Charcoal,		
Cloth, waxed, new,	feet,	100
Colors, union, 18′ × 12′,		1
" " 8′ × 5½′,		1
Composition, greasing,	lbs,	100
Copper, sheet, thick,	"	50
" " thin,	"	150

* This list has been given as likely to be useful to the Military Engineer for reference in similar cases —[Ed]

Draft, equipment, drag ropes, &c., in proportion for 8 siege carriages,	
Engines, water, complete, small,	1
" " " hose, leather, spare,	4
" " " screws,	4
" " " suction pipes,	1
Formers, cartridge, siege gun, 18 lbs.,	3
" " " 9 lbs.,	5
" " mortar, 8 inch,	4
Funnels, copper, medium,	3
Fuzes, filled, common, 8-inch,	4,000
" " spherical case,	3,200
Gins, large, complete,	1
Gin, falls,	1
Glasses, hour,	1
Gratings, or Garland's shot,	6
Gurnie, bell metal,	1
Half wrought materials, staves for sponges,	24
" " " axletree, beds, for siege guns,	4
" " " felloes, " " "	32
" " " naves, " " "	4
" " " spokes, " " "	32
Heads, rammer, 18 lbs gun,	9
" " 9 lbs "	15
" sponge, 18 lbs "	9
" " 9 lbs "	15
Implements, gun, aprons, canvass, siege gun,	16
" " cartouches, leather, large,	24
" " hammers, with turnscrew,	16
" " wrench,	8
" " handspike, common,	108
" " " iron mortar,	20
" " " " traversing,	10
" " knives, circular, siege, sets,	2
" " ladles, copper, siege ordnance,	16
" " scrapers, for shells,	8
" " sockets, portfire,	48
" " tamping, siege gun 18 lbs.,	6
" " " " 9 lbs.,	10
" " " mortar, 8-inch,	8
" " tangent scales, complete,	16
" " wadhooks, siege,	16
" " wrenches, iron,	4
" fuze, augers, hand,	4
" " bags for blowing and bursting powder, 18 lbs.,	500
" " " " " " 9 lbs.,	800
" " benches,	2
" " blocks, driving,	2
" " " setting,	2
" " drifts, of sizes,	12
" " engines for drawing,	1
" " gauges, composition, or markers,	2
" " knives,	12
" " ladles, composition,	2
" " mallets, driving or setting, large,	2
" " " " " small,	2
" " pincers, brass or copper, ..	2
" " rougheners, steel,	6

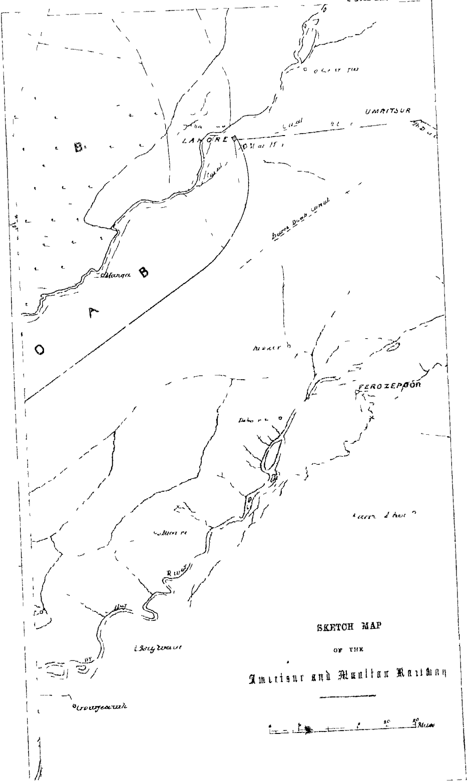
Implements, fuse, setters, common, large, 8 inch,		2
" " " spherical case,		2
" " vices, hand,		2
Implements for proving shells,	sets,	1
Instruments, measuring rods, wooden,		6
" " tapes, 100 feet,		2
" perpendiculars, gunners,		2
" quadrants, plumb,		2
" scales, diagonal, brass,		2
" telescopes,		1
Iron, flat bar and round,		160
Jacks, hand, double,		2
Lanthorns, dark,		2
" Muscovey,		2
Laboratory materials, of sorts,		
Light balls,		200
Locks, pad, iron,		
Match, gun, common,	skeins,	10
" quick,	lbs,	10
Measures, copper, powder, 1 to 8 lbs,	sets,	1
Mortars, brass,		1
" pestles, brass,		1
Platforms, traversing, wooden, 18 lbs,		4
" gun, complete,		8
" mortar,		4
Portfires,		1,440
Powder, ordnance, service,	lbs,	96,000
" musketry "		16,000
Quoins, mortar, 8-inch, 2 in a set,		8
Quoins, siege, ordnance,		32
Rockets, signal, 1 lb,		16
Rockets, staves, signal,		16
Rope, Europe 3 inch,	fathoms,	50
" " 2½-inch,	"	50
" " 2-inch,	"	150
" " 1½-inch,	"	100
Scales, copper, with beams, large,		1
" " " medium,		1
Scale boards,		1
" beams, large,		1
" " chains,		1
Screws, elevating, garrison gun, spare,		4
" iron, for woodwork, of sizes,	lbs,	50
Shells, spherical, empty, loose, 18 lbs,		600
" " " " 9 lbs,		1,000
Shells, common, empty, loose, 8 inch,		3,200
" carcass, filled, 8-inch,		80
Shot, case, fixed to bottoms, gun, 18 lbs,		840
" " " " " 9 lbs,		1,400
" round, loose, gun, 18 lbs,		3,600
" " " " 9 lbs,		6,000
Sieves, brass wire, medium,		1
" " " fine,		1
" leather tops,		1
" " receivers,		1
Skins, sheep, undressed,		50
Sponges, siege gun, 18 lbs,		12

Sponges, siege gun, 9 lbs,		20
„ mortar, 8-inch,		16
Staves, colors, union, large, complete,		1
„ „ „ small,		1
Tar and grease, mixed,	lbs,	30
Tools, artificers,		
„ „ saws, tenon,		3
„ laboratory,	sets,	1
Tow,		
Triangles for scales,	lbs,	1
Wads, common,		4,200
Weights, brass, 28 lbs to 1 oz,	sets,	1
„ „ 8 oz to $\frac{1}{2}$ dram,	„	1
Wheels, wooden, siege carriage, spare,		4
Windlass for gin,		1
Zinc,	lbs,	

MISCELLANEOUS STORES, CALCULATED WITH REFERENCE TO ARMAMENT, AS ABOVE, AND OF A MAXIMUM STRENGTH OF 1,000

Accoutrements in proportion to 250 stand of small arms,		
Bags, sand,		24,000
Bamboos, 1st size,		50
„ 2nd „		100
„ small,		200
Boxes, ammunition, common, camel,		
„ tin, for 500 percussion caps,		1,200
Caps, percussion,		600,000
Cartridges, balled, percussion, wall piece, $7\frac{1}{2}$ drams,		25,000
„ „ „ musket, $4\frac{1}{2}$ „		500,000
Chests,		
Chevaux de frieze,		300
Cloth buntin, blue, red, and white, 10 yards of each,		30
Chokers, fascine,		20
Cloth, linen, old,		
Corks,		
Cotton wick,	lbs,	10
Formers, cartridge, wall-piece,		5
„ „ musket,		10
Iron, country,	lbs,	200
Knives, laboratory,		10
Lead, pig,	cwt,	30
Ladles, iron, melting,		2
Line, seizing, common,	skeins,	50
Mallets,		
Musketry muskets, percussion,		250
„ wall-pieces, „		50
Nails, iron, spike, 7-inch,		200
„ „ „ 5 „		400
„ „ of sorts,		2,000
Paper cartridge,	reams,	52
Pawlins, waxed, magazine, large,		2
„ „ „ small,		10

PLATE XXX.


UMRITSUR
LAHORE
FEROZEPOOR
B
B
A
O
SKETCH MAP
OF THE
Amritsur and Mooltan Railway
Miles

Plank, 3-inch, deal,	running feet,	500
" " sissoo or saul,	"	500
Powder, musketry, service,	lbs,	2,500
Rope, country, 3 inch,	fathoms,	200
" " 1½ "	"	100
Scissors, laboratory,		4
Shells, common, empty, loose, grenade,		10,000
Steel, Europe,	lbs,	20
Timber, saul or sissoo,	cub ft,	250
" fir, "	"	25,000
Tin, block,		
Tools artificers saws, hand,		20
Tools, intrenching, axes, felling,		60
" " bill hooks,		20
" " axes, pick,		60
" " shovels, common,		60
Twine, country,	lbs,	50
" Europe,		30
Wrappers, ammunition,		8

ENGINEER STORES, IN ADDITION TO THE ABOVE, CALCULATED FOR A DEFENCE OF TWO MONTHS, WITH GARRISON AS ABOVE

Bags, sand,		24,000
Barrows, hand,		50
" wheel,		100
Buckets, wooden, water,		30
Carriages, cart, hand, or platform,		5
" artificers or store,		1
Jacks, hand, double,		1
Ladders, scaling, 10 feet lengths,		20
Tools, artificers, adzes, carpenters,		15
" " carpenters,	sets,	1
" " smiths,	"	1
" " miners,	"	1
" " jumpers, miners,		10
" " " " smallest,		10
" " levels, ground, square, with bob,		10
" " priming wires, miners,		15
" " saws, hand,		50
" " " cross cut,		25
" " " pit,		15
" " ladles, miners,		5
" " hammers, sledge, large,		25
" " " " small,		25
" " tamping bars, miners,		5
" " stones, grinding, large,		15
" intrenching, axes, felling,		50
" " " pick,		350
" " bills, hand,		50
" " " hook,		300
" " crow bars, iron,		30
" " hatchets hand, with handles,		15
" " helves, axes, pick, spare,		1,000

Tools, intrenching, sap forks,	16
„ „ shovels, common,	500
„ „ „ miners,	50
„ „ spades, common,	250

The armament in this statement is that which has been recommended by the Chief Engineer, and the stores are either in proportion to the armament or to the maximum garrison There are probably some omissions in this statement, and the proportions may not be according to established usage I should, therefore, recommend that the matter be referred to the Ordnance Commissariat Department, as soon as the armament is definitively settled I should like to have some experiments tried with the 18-pounders now in the Fort, to test the capabilities of the ramparts for standing the concussion from the discharge of heavy ordnance before the number of pieces is increased In the lower Fort, at Kohat, the scarp side of the ditch is maintained at an unnatural slope, (if I may use the term,) by a mere facing of mud bricks I am not sure that the works built thus will stand the firing of heavy guns until some experiments are made

A W GARNETT

ABSTRACT OF ESTIMATE

c ft		R.	A	P
54,45,270	Earthwork, excavation, ordinary, at Rs 5 per 1,000,	27,226	5	7
33,19,483 5	Earthwork, excavation and filling in, at Rs 7 per 1,000,	23,236	6	2
3,39,493 76	Earthwork, underground excavation, at Rs 50, per 1,000,	16,974	11	0
12,255	Mud work, at Rs 3 per 1,000,	367	10	4
1,78,992 63	Pucka masonry brickwork (plain), at Rs 20 per 100, .	35,798	8	5
84,715 91	Pucka masonry brickwork (arched), at Rs 22 per 100,	18,637	8	0
6,07,499 46	Pucka masonry rubble work, at Rs 18 per 100,	1,09,349	14	5
5,59,687 6	Kucha masonry brickwork, at Rs 7 per 100,	39,178	2	1
2,10,057 81	Kucha masonry rubble work, at Rs 7 per 100,	14,704	0	9
46,917 5	Kucha pucka masonry, at Rs 15 per 100,	7,037	10	0
s ft				
10,999 55	Flat roofing, pucka, at Rs 40 per 100,	4,399	13	1
16,427	Flat roofing, kucha, at Rs. 30 per 100,	4 928	1	7
25,875 44	Pucka flooring and plastering, at Rs 10 per 100,	2,587	8	8
c ft				
14,082 82	Pucka masonry in wells and staircases, at Rs 24 per 100,	3,379	14	0
10,800 82	„ paved in gun platforms, at Rs 45 per 100,	4,860	5	11
r ft				
650	Closed drains, pucka brickwork, at Rs 2-8 per foot,	1,625	0	0
2,000	Open wall drains, pucka brickwork, plastered, at Rs 0-12 per 100, ...	1,500	0	0
	Carried forward, ...	3,15,791	8	0

ABSTRACT OF ESTIMATE—(*Continued*)

		R	A	P
r ft	Brought forward,	3,15,791	8	0
1,500	Open wall drains, pucka plastered, only, at Rs 0 5 per 100,	468	12	0
7,190	Open drains, stone and pucka plastered, at Rs 0-2 6 per 100,	1,123	7	0
s ft				
1,056	Bridge platforms, sissoo timber, at Rs 2 per 100,	2,112	0	0
c ft				
2,594 26	Fir timber in bridges, blindages, &c, at Rs 1-4 per foot,	3,242	13	2
364 15	Sissoo timber gates, magazine, &c, at Rs 2-12 per 100,	1,001	6	7
s ft				
464	Sissoo in gates, 3 inches, at Rs 4 per foot,	1,856	0	0
3,686 75	Timber in doors and windows, at Rs 1-8 per 100,	5,530	2	0
lbs				
6,700	Iron work in drawbridges, &c, at Rs 0 4 per lb,	1,675	0	0
372	Copper work in magazine, &c, at Rs 1-8 per lb,	558	0	0
s ft				
8,744 28	Painting, at Rs 2 8 per, 100,	218	9	6
7,99,600	Turfing glacis, at Rs 0 8,	3,998	0	0
	Total Fort Estimate,	3,37,575	10	8

APPENDIX I OUTWORK

		R	A	P
c ft				
16,90,000	Earthwork excavation, ordinary, at Rs 6 per 1,000,	10,140	0	0
79,907	Excavation in rock, at Rs 50 per 1,000,	3,995	5	7
780	Pucka masonry brickwork, plain, at Rs 21 per 100,	163	12	10
6,227 51	Pucka masonry brickwork, (arched,) at Rs 24 per 100,	1,494	9	8
38,135 76	Pucka masonry rubble work, at Rs 18 per 100,	6,864	7	0
s ft				
4,444 94	Pucka plastering, at Rs 12 per 100,	533	6	3
290	Sissoo timber in bridge platform, &c, at Rs 2 per foot,	580	0	0
lbs				
3,216	Iron work in drawbridge, &c, at Rs 4 per lb,	804	0	0
	Total outwork,	24,575	9	4
	Total,	3,62,151	3	7
	Allowance for contingencies,	18,107	8	11
		3,80,258	12	6

APPENDIX II

	R	A	P
Compensation for villages pulled down, and various property removed,	25,701	2	0
Grand Total Rupees,	4,05,959	14	6

A W G

From Brigadier NEVILLE CHAMBERLAIN, C B, *Commanding Punjab Irregular Force, to the Military Secretary to Chief Commissioner, Punjab*

Camp Kohat, 30th December, 1856

SIR,—In compliance with instructions received, I have now the honor

to place before the Chief Commissioner my opinion of the works of the Kohat Fort, either executed or proposed, as also on its proposed armament

Before, however, entering into any details, I think I ought in the first place to bring prominently to notice, what I believe the present condition of the Fort to be, and what it still must remain even after it has been strengthened by the addition of the whole of the works now estimated for

Since Sir Charles Napier first "recommended the repair of the Old Fort as being exactly where it ought to be, and needing very little to make it a perfect protection to the town,"* Rs 2,71,432-15-2 (including Rs 25,701 paid on account of compensation) have been expended in fortifying those old remains, and all that portion of the town which formerly afforded shelter close up to the defences of the place, and impeded its fire, has been swept away, and removed out of gun range

But notwithstanding all these improvements at so heavy an outlay, the inherent defects of the position appear to me to be of such a nature as to forbid the idea of the present work ever possessing those elements of defence which would ever entitle it to the name of a fortress, (unless indeed it were surrounded by a fresh line of works, and the present Fort be viewed, merely as an inner line of defence or citadel,) and as in a question of this nature, government must necessarily depend upon its officers for information, and on so important a subject the real facts cannot be too prominently made known, I feel that I have no option but to state as I have done, what I believe to be the case, leaving it, of course, to others to confirm or upset that opinion

If my judgment be correct, there can be no motive for perfecting the defences, further than is necessary to ensure the following objects —

Firstly To secure its safety as a depôt for arms, ammunition, military stores of all kinds, and grain

Secondly That it may afford a secure asylum for persons and property on any occasion of the troops having to leave the cantonment unoccupied

Thirdly To be able by its fire to defend the town against any descent of the hill tribes in mass

* "Indian Mis-government,' letter, dated 11th March, 1850, to Lord Dalhousie, page 126.

When perusing the remarks I have now to offer upon the Executive Engineer's propositions and estimates, it will be necessary always to bear in mind the opinion I have expressed as to the inherent weakness of the site, and what I conceive to be the object of the Fort, for every thing that I say is of course based on the supposed correctness of those conclusions

Perhaps my clearest way of explaining myself is to class the proposals and estimates under three headings, viz, Indispensable, Desirable, and Unnecessary, and with reference to the two first named, to distinguish as far as possible the relative importance of each work

---

ABSTRACT OF ESTIMATE

			RS
INDISPENSABLE*	1	Gates to the upper and lower forts,	653
	2	Completion of the upper fort ramparts and scarp on the south-west fronts,	9,000
	3	Postern between upper and lower fort,	3,724
	4	Levelling the interior of the upper fort,	2,334
	5	Construction of a range of store houses and barracks, in the south angle of upper fort,	17,300
		Total Rupees,	33,011
DESIRABLE	1	Bridge over lower fort ditch,	1,810
	2	Gun carriage sheds (for ten carriages) in lower fort,	2,072
	3	Second range of store houses and barracks in north and west fronts of upper fort,	29,500
	4	Barbette platforms in all the bastions,	4,860
	5	Completion of covered way to upper fort,	5,400
	6	Completion of glacis of upper and lower fort,	12,000
		Total Rupees,	55,642
UNNECESSARY	1	Second range of gun sheds in lower fort,	2,000
	2	Masonry traverse and expense magazine in lower fort,	2,164
	3	Bombproof covering to wells,	1,392
	4	Increasing thickness of parapets lower part,	3,270
	5	Entrance to covered way, north front,	1,000
	6	Lowering of hill to north of fort,	5,000
	7	Out-work on hill to north of fort,	24,575
	8	Caponniere between out-work on hill and fort,	2,850
		Total Rupees,	42,751

The only works I can recommend to be included in the Budget for 1857-58 are those specified in the first list, and as their necessity cannot I think be questioned, I think they should be commenced upon at once, and completed without delay, for the Fort in its present condition does not fulfil any one of the three conditions I suppose to be required of it.

The works named in the second list, should I think be entered in the Budget for 1858-59 whilst those pronounced by me unnecessary can either be struck out altogether, or be again taken into consideration on the others being completed.

These remarks conclude all that I have to say with reference to "works proposed," and I will now in as few words as possible proceed to comply with that portion of the Chief Commissioner's instructions which requires it of me to express an opinion on the "works executed."

My ignorance of everything connected with the price of labor and materials, disqualifies me from expressing any opinion as to the cost of the works executed, and having seen the shafts it was found necessary to sink right through, and below the bottom of the mound, (the old site, and around and upon which the upper Fort has been constructed,) before a proper foundation could be obtained for the foundation of the magazine*, to rest upon, I have had an insight into the nature of the difficulties, and know how expensive it must have been to overcome them.

Wherever masonry has been used, the works appear to be solid and not likely to suffer from the weather.

The kucha buildings and earthen works were exposed to a very severe and unusual trial last summer, and as a matter of course, suffered, but perhaps not more than was to be expected. The repair of these works will always call for outlay and require attention, but much damage and loss may I believe be avoided by plastering the exposed faces at the right moment, and in sufficient time to permit of the mud drying *thoroughly* before the summer or winter rains fall.

In conclusion of this subject I may add, that the bastions of the Lower Fort were in May last subjected to the test of having a few rounds fired

* The shafts, 8 in number, were 44 feet deep. The foundations of other portions of the defences are from 35 to 15 feet below the level of the *present* ditch, which had to be sunk 10 feet below its former level. Forty eight piers, constructed under ground, of an average depth of 18 feet, spanned by semicircular brick arches, 3 feet thick, support the west, north, and east fronts, comprising a mass of 150,000 cubic feet of masonry hid from view.

from them, from the 18-pounder garrison guns, and stood well, a further trial is necessary before they can be pronounced fit to withstand the concussion of continued firing from heavy ordnance, and this shall be done at an early date

Twenty-four is the number of pieces* recommended for the armament, of the Fort Assuming this to be the proper proportion for such a work, I would still suggest a modification both of class and calibre, for the transport of so many heavy pieces with proportionate quantity of ammunition and stores, could not be accomplished without considerable expense, and my belief is, that a proportion of lighter pieces would be found equally useful for the purpose likely to be required of them, and they would at the same time possess the very great advantage of being available for use in the field if required

The following is the armament I recommend —

Description of Ordnance		*No of Pieces.*
Iron gun, garrison,	18-pounders,	3
" " "	9-pounders,	3
" howitzer,	8-inch,	2
" mortar,	8-inch,	2
Brass gun, field,	9-pounders,	2
" " "	6-pounders,	2
" howitzer, field,	24-pounders,	2
" " "	12-pounders,	2
" mortar, field,	5½-inch,	4
" " "	4⅖-inch,	2
	Total,	24

The iron 8-inch howitzers and brass mortars, are in my opinion the pieces most needed, and I advocate their being the first to be despatched Whether for the defence of the Fort or service in the field, they may be turned to account on this border when other pieces could produce little or no effect Only in May last, some experiments were made in my presence with the pieces of the Light Field Battery from the bottom of the pass (Kohat), and the result was to establish their inability to afford material assistance if the summit were held by the Afreedies, and the infantry had occasion to possess themselves of it, the 24-pounder howitzer was at last made to throw a shell on to the top of the ridge, but not without having to give the piece undue eleva-

* 18 pounders, 6, 9 pounders, 10, 8 inch mortars, 8

tion, and then the range was too great for anything like effective practice

A couple of 8-inch howitzers properly directed would rob the hill of its strength, and save us loss of life, and the Government, family pensions

NEVILLE CHAMBERLAIN

[The Brigadiers' proposal were substantially sanctioned by Government, and the work executed in accordance with them —[ED]

No XXVI.

UMRITSUR AND MOULTAN RAILWAY

In March 1856, the Scinde Railway Board requested permission of the India House to commence a survey of the country from Moultan to Lahore and Umritsur, with the object of completing the combined system of steam transit by land and water, so long advocated by their chairman In July 1856, the permission to conduct the survey was given by the East India Company, and measures taken for its immediate commencement Of the political and commercial value set on this link in the chain of communication by the local authorities, the following extract from the report from the Punjab Government in 1856, will be sufficient evidence

"So far as the commercial and material interests of the Punjab are concerned, there is a proposed line from the north-east to the south-west which is of greater consequence to the country than any public work, or any number of works that could be specified A glance at the accompanying map will show that Northern India has two natural divisions, *first*, the Provinces of the Ganges and its tributaries, *second*, the Provinces of the Indus and its tributaries In the first or easterly division, the stream of trade and wealth must ever flow down the valley of the Ganges to the natural outlet of Calcutta In the second or westerly division, if the power of art and science be brought to the aid of nature, the commerce could follow the direction of the Punjab rivers to the Indus, then down the valley of the Indus towards the rising port of Kurrachee, which is destined to be, to the north-west of India, what Calcutta is to the north-east To this port would come the products from north-western India, and from the Central Asian countries beyond

that frontier, and in exchange for these, the products of European countries In this same direction, there would also arrive the vast quantities of Government stores and material for the military and public establishments in that quarter, and large numbers of European travellers would frequent this line (in preference to the Eastern route), on account of its comparative shortness and proximity to overland passage to Europe

"For the opening up of this western route the importance of which upon general considerations is so evident, it is proposed in the first place, to establish communication by rail and steam from Kurrachee upwards to Moultan, just above the point where the Punjab rivers join the Indus For the first section of this line, a railroad from Kurrachee to Hyderabad on the Indus, a distance of 123 miles has been undertaken by the Scinde Railway Company * At first, the line may be continued thence up to Moultan, by steamers on the Indus, to be followed by a railway as soon as it can be constructed, there would then remain to be constructed a railroad from Moultan to Lahore and Umritsur, to join or cross (or rather continue) the great north-western line between Calcutta and Peshawur It is this last-named railroad, from Moultan to Lahore and Umritsur, which immediately concerns the Punjab, and the Supreme Government have directed complete inquiries on the subject to be made It will now be proper to state briefly what the advantages and facilities of the line are likely to be

"The northern terminus of the line will be Umritsur, which is not only the first mart in the Punjab, but also one of the first commercial cities in Upper India Its merchants have dealings, not only with all parts of India, but also with many parts of Europe on the one hand, and of Central Asia on the other To this city there come the choicest Asiatic products, the wool of Thibet, the shawls of Cashmere, the dried fruit and spices of Afghanistan, the carpets of Turkey, the silk of Bokhara, the furs and skins of Tartary, the chintzes and leather of Russia In return for these arrive the piece goods and iron of Europe, the fabrics of Bengal, the sugar of Hindostan and the Punjab To the same emporium are gathered all kinds of indigenous produce of the Punjab Of this trade, amounting, according to reliable returns, to three and-a-half million

* This line is completed and open, and steamers ply regularly on the Indus. The voyage upwards still however very tedious —[ED]

pounds sterling per annum, a large portion proceeds to and from Calcutta by the Grand Trunk Road, another portion to Bombay by difficult and laborious land routes, through Central India and the desert routes of Rajpootana, and a third portion (and at present the least portion) to Kurrachee, by water carriage on the Indus and its tributaries. Of this traffic, then, nearly all would be diverted to the proposed railroad from Umritsur to Moultan, and thence to Kurrachee. From these parts, most things intended for export would not go to Calcutta, if there were facilities for going to Kurrachee, and of those things destined for Bombay, all would go by the rail to Kurrachee *viâ* Moultan, instead of the arduous route through Central India. In the same manner all the imports for Umritsur, and other parts of the country between Delhi and the N. W. Provinces Frontier, and the regions beyond it, which now come from Calcutta or from Bombay by land, would proceed to Kurrachee, and thence upwards by rail.

" But besides the noble traffic above indicated, which is of general as well as local interest, there is already a traffic of some magnitude between the Punjab and Kurrachee. So strong is the tendency of trade towards the natural port and outlet, that large quantities of indigenous produce creep and labor in clumsy native craft down the five rivers. In this manner, hundreds of tons of cereals, linseed, sugar, saltpetre, and indigo pursue a tedious way over 400 miles of the five rivers to the seaboard. The water traffic is greatest on the Sutlej, next on the Jhelum, then on the Indus, and lastly on the Chenab and the Ravee. The united traffic of the rivers up and down (by far the greater part, say four-fifths, being down traffic), as ascertained by registration of boats at the junction point, Mithunkote on the Indus, is not less then 700,000 maunds, or 35,000 tons per annum. Now if the rates of carriage by rail should be kept low, so as to attract commodities which can only afford to pay for cheap transit, then it may be certainly presumed, that of the above quantity all that pertains to the Sutlej, the Ravee, and the Chenab, and a part of that belonging to the Jhelum, will be diverted to the Umritsur and Moultan Railway. The present means of navigation being wretched, and the rivers being difficult, the existing water traffic would preferentially take the railway, provided always that the cost of transit be cheap. It is indeed, for the sake of this indigenous traffic that every well-wisher of the Punjab must be anxious to see the day

when the rail shall be opened from Umritsur to Moultan. The traffic may be already considerable and promising, but it is now as nothing compared to what it would become, with the advantages of a rail.

"Again, if the advantages, present and prospective, of this line, when constructed, are great, so also are the facilities for its construction remarkable. Though the country situated above its northern terminus is rich and highly cultivated, yet the particular tract through which it will run is for the most part poor. Between Moultan and Lahore, a distance of 240 miles, the country is a dead level, hard and waste. In the first place, then, there will be no cultivated or inhabited ground to be bought up. The price for the land will be almost nominal. There are no engineering difficulties whatever to be met with anywhere between Lahore and Moultan. The Doab, or country lying between the two rivers Sutlej and Ravee, is elevated in the centre, and the sides slope gently off towards the rivers. From the centre or back-bone of the tract, there naturally run drainage channels to the rivers, consequently, while a road traversing the Doab, near the banks of either river, must cross or be intersected by numerous little streams, a line constructed in the centre would meet none of them. But the railroad would run near the central or dorsal ridge, parallel to the course of the new Baree Doab Canal, and consequently, the line will, perhaps, not meet with any stream whatever. There being no streams, nor depressions, nor elevations, there will, consequently, be no bridges, cuttings, or embankments, on at least four-fifths of the distance. As it approaches Moultan, the line would have to be carried across a few small irrigation canals, and to be partially raised. In short it would be difficult to select, or even imagine, a champaign more suited for the cheap and easy construction of a railway than the country between Lahore and Moultan. Between Lahore and Umritsur the country is fairly cultivated, and generally level. It offers no engineering obstacles. But there would be three or four small streams, and one canal to be bridged. As regards materials, the iron would come from England; timber and wood of the best quality is obtainable from the hills by water-carriage, fire-wood exists in the utmost abundance, kunkur would be generally procurable for at least half the distance, masonry would not be much needed, if it were, there are ample facilities for brick-making, the population near the line is sparse, but labor is largely procurable from other parts of this country for any great work

'The absence of physical and engineering difficulties is indeed most fortunate For economy and even cheapness of construction will be essential to enable the railway authorities to fix the transit line at low rates The passenger traffic and the more valuable commodities and products would be considerable, and might bear tolerably high rates But for a mass of produce great in bulk, but comparatively less valuable lower rates will be indispensable For the goods trains, speed will generally be of less consequence than cheapness of hire It is upon this condition, namely, that of moderate hire, that the rail may be expected to supersede the native river boats "

Report from William Brunton, Esq , C E , *Superintending Engineer to the* Chairman *and* Directors *of the Punjab Railway Company*

Lahore, 15th June, 1857

Gentlemen,—I beg to forward plans, sections, and estimates for a line of railway uniting the towns of Umritsur, Lahore, and Moultan

My estimate is for a single line of railway of 5 feet 6 inches gauge, complete with every appliance to render it fully effective, both as regards the carriage of passengers and goods, and the public safety, with sufficient rolling stock, tools and machinery to work the same, and every way in accordance with the recommendations of the Consulting Engineers of the Indian Railway Companies, sanctioned by the Honorable Court, bearing date, London, March 7th, 1856

I have as far as possible chosen the highest ground between the rivers Ravee and Sutlej, in order to keep above the annual inundations, and where this has been impracticable, I have provided such drainage as from the information I have obtained will be sufficient to keep the works perfectly secure in case of floods I shall personally inspect every portion of the ground during the next flood, in order to be satisfied that I have founded my calculations on correct data

The working expenses of a line so laid down must of necessity be small Being nearly level, the consumption of fuel will be proportionally low, and being almost entirely free from curves, the wear and tear of the rolling stock will be trifling in comparison with lines not having the same advantage

The pay also of natives is about 20 per cent of that in England for labor of the same description

I have estimated but not shown the position of a branch line from the

Lahore station to the banks of the Ravee My reason is, that I wish to see the country over which it must pass inundated (which is the case every year) prior to fixing the most advantageous site for such branch Whichever site I decide on, my estimate will be adequate for its construction

I have consulted the wants of the Mean Meer Cantonment, and have allotted a station at each end of their lines The stations at Lahore, Umritsur, and Moultan, I have placed more especially with a view to native passenger traffic, which will be the main source of revenue from passengers, they are also in suitable positions for the delivery and reception of goods

It is possible (I may say certain) that near each station between Lahore and Moultan, natives will form in time large villages I should recommend you to make such arrangements with the Honourable East India Company as shall give you the control over the erection of any buildings within, say one mile, from each station, that the villages may be constructed with regularity, and proper sanitary measures taken, as you may be advised by your engineer for the time being

Over the whole length of the line, timber for fuel is to be obtained in abundance

At every ten miles along the line, wells will have to be sunk at an average depth of 80 feet, at which depth abundance of water can be obtained This is a work which should be proceeded with immediately, so as to provide for the wants of the workmen

The station-houses also should be erected without delay, as they would form head-quarters for my residents, during the construction of the line

I have formed the line entirely on embankment, I find it necessary, even where the surface of the ground would appear to warrant a cutting The reason for this is, that in the rainy season any place below the natural surface becomes a pond, if level, and if at an inclination, a bed for a stream

The quantity of land which will be occupied by the railway and station-plots, will be 1,700 acres, and liberty required to take side cuttings exclusive of this amount This quantity provides for a double line of railway

In my estimate you will perceive I have provided for grassing the slopes of embankments, this may seem an unnecessary expense to parties unacquainted with the character of the rains in India, but it is absolutely necessary in order to keep the slopes perfect during the rainy season

The fencing estimated for is post and rail, and I propose planting a

herds of cattle that range over the whole Doab, render a fencing on every portion absolutely necessary, to secure the public safety

The ballast I propose using principally is kunkur (a limestone found in different parts of the Doab), where this is at such a distance from the line as to render its use too costly, I shall substitute hard burnt bricks broken to size, either of these materials will form excellent ballast

At every mile along the line I propose putting occupation level crossings, this distance will, I believe, be satisfactory to all parties I have taken the opinion of several gentlemen in authority over the different districts, and they state it will be ample The canal engineers, in consequence of a crossing entailing such an expense in bridges, approaches, &c, &c, only put one every three miles, but this is at a distance very detrimental to parties whose ground may be severed

My estimates are made on fair local prices for each description of work and on the price of all materials, &c, which must be imported, I have added an amount fully ample for charges in laying the same on the ground, I am convinced the railway can be completed for the sum named

If a responsible English contractor will undertake it for such a sum, you would not, in my opinion, do wrong in letting it, but from what I hear, of the disagreements between contractors and railway companies in India, the said contractor, whoever he might be, should be tightly bound down, and should give good securities in case of failure There are plenty of native contractors here, men who have completed large works on different roads and canals, who would be glad to take from twenty to forty miles of line each, exclusive of the permanent way, and unless you can obtain excellent security for the proper construction of your works from some English contractor, I should recommend everything, except the permanent way, to be let in the above mode to native contractors, in which case I believe my estimate would be found to exceed the actual cost

In ordering the chairs, 10,000 should be adapted for receiving check rails, which may be a flat bar, length not less than 15 feet. Sleepers, of good quality, for permanent way, I can get here delivered on the ground for Rs 3 each

All other articles belonging to the permanent way, with locomotives, iron work for carriages and waggons, tools, and implements of every description, will have to be sent from England

I recommend (in order that no delay may occur in our obtaining material) that rails and all appliances for same, necessary for permanent way, be immediately ordered and sent to Kurrachee From that place to

Moultan they have to be sent by native boats, necessarily involving a loss of time If this is done, and proper diligence used in getting them up the Indus, the subject of obtaining the necessary supplies of material needs no further comment I believe there are plenty of native boats, it is a question of delay, in consequence of the time these take making a trip, the disadvantages arising from which, immediate prosecution will obviate

The locomotives you send out should be adapted for burning wood They should be light also, which tends to decrease the wear of permanent way This involves engines of less power than those now generally made in England, but our line is so level that such powerful engines are not required Forty locomotives will work the line Twenty 6-wheel engines, leading and trailing wheels, 3 feet 6 inches diameter, driving wheels, 6 feet, 12-inch cylinders and 20-inch stroke, weight not exceeding 20 tons, and twenty 6-wheel engines, leading wheels, 3 feet 6 inches diameter, driving and trailing wheels, 5 feet, diameter coupled, 14-inch cylinders, and 20-inch stroke, weight of engine not exceeding 22 tons, in both cases, exclusive of tender, which should carry 1,200 gallons, on six wheels, 3 feet 6 inches diameter, each engine and tender to be provided with a light frame or roof covered with painted canvas, carried on uprights from the engine frame and tender, respectively, the tender roof being higher than the engine roof, so as to work perfectly clear and to lap over each other 9 inches

Every portion or part of each engine and tender in each set of twenty to be made from one template, so that any piece of an engine shall fit and be applicable to perform the same duty for any other of the set

I should recommend you to have the wood work of all your carriages and wagons made here, the iron work being sent from England, and no delay should take place in making arrangements for such work, viz, for preparing shops and getting timber cut, so as to have it properly seasoned. I find the native workmen clever and intelligent, and with English foremen over them, can be made to turn out exceedingly good work

The staff I should require during the construction of the line would be, six first class engineers, residents, over certain districts, six second, and six third-class, each first-class having two assistants, one first-class engineer, a good practical man, to take charge of the principal office and drawing department

The number of inspectors required it is now impossible to state, it will depend on what works are being proceeded with at the same time These men can be obtained in this country.

I am of opinion that I could complete this line of railway, ready for opening, in four years from this present date, if I have every facility for so doing afforded me

That the passenger and merchandise traffic are sufficient even now amply to repay the outlay, the statistical reports you already have from the Government officers fully prove, but in my opinion the increase of these sources of profit will be augmented to a degree that it is impossible to calculate, when there is an outlet for the products of the country At present there is none, the natural result being, that only sufficient for the wants of the immediate vicinity is produced , and, added to its being a source of profit, the present position of India forcibly points to the absolute necessity of rapid communication with all parts of a country made up of so many discordant elements

As your proposed lines of railway in connection with the river and railway communication to Kurrachee, will form the main artery through which the whole of the traffic from the Punjab must naturally pass, I should, to complete the scheme, recommend that the cost of extending the line from Lahore to Peshawur be ascertained as quickly as possible

W BRUNTON

NOTE BY THE EDITOR

On the 8th February, 1859, the first sod of the Punjab Railway was formally turned by Sir John Lawrence, then Lieutenant-Governor of the Punjab, and work which had actually begun a short time before steadily proceeded for rather more than a year, when the unfortunate disagreements between the Agent and Chief Engineer of the Railway, which ultimately led to the removal of both, caused great hindrance to progress Other unforeseen difficulties also arose The principal contracts were given to native contractors, who failed in their engagements, not from dishonesty, but from want of experience, and the serious difficulties arising from the great scarcity of labor Under the able management of the present Chief Engineer, Mr Joseph Harrison, such difficulties were, however, gradually overcome, but not without having to execute the the chief portion of the work by daily paid labor through the District Engineers, and in 1862, the first section of the line from Lahore to Umritsur, 32 miles, was formally opened by the Lieutenant-Governor, and traffic has continued on it uninterruptedly ever since

A small section, 11 miles long, from the Steam-boat Ghât on the

Chenab up to the city of Moultan, was also opened shortly afterwards Of the 218 miles from Lahore to Moultan, about 170 are already completed, and the whole line will shortly be open

It would be difficult to find a more extraordinary line, in some respects, than the one now described The country is so flat and open, that, for 114 *continuous miles the line runs as straight as an arrow* down the heart of the Doab, and in the whole distance of 250 miles, there is scarcely a bridge larger than an ordinary culvert The only exceptions are where the Railway is carried over two branches of the Baree Doab Canal on Warren's Girders, (80 feet span,) at a considerable skew, and across one or two native Canals near Moultan The gradients nowhere exceed 1 in 600, and are in general much flatter

The ballast used has been chiefly broken brick from the ruins of old Lahore, which appear to furnish an inexhaustible supply Brick is the material every where used for all buildings on the line, and the Punjab deodar is the only wood

Between Lahore and Moultan no place of any size larger than a third rate village is passed, and even the few towns on the bank of the Ravee were too insignificant to necessitate a circuitous route on their account

The original Estimate amounted to about £6,000 per mile, including rolling stock, but it is believed this has since been increased All material and stores from England were shipped to Kurrachee, and thence brought by native boats or steamer up to Moultan or Ferozepore, whence they were carried by land on to the line—the Ravee being nearly unnavigable

The Rails are very light, weighing 66 lbs only to the lineal yard, but as low speeds and cheap rates are intended, the weight thus saved where carriage was so difficult, more than compensated for any supposed disadvantage of using rails lighter than usual Owing to the difficulty of procuring sleepers, 40 miles of Greave's Patent Permanent Way have been imported and laid down

A view of the Lahore Station is given, and a Plan and Elevation of the Umritsur Station are here added

The continuation of the line from Umritsur to Delhi has been sanctioned, by which a junction will be effected with the East India Railway, and the line is now being marked out I hope to be favored with some details of the works on this line (a very interesting one in an Engineering point of view) so as to be able to communicate them in an early number

J G. M

No XXVII

SCANTLINGS OF TIMBERS—MYSORE

By Major R H. Sankey, R E, *Assistant to Chief Engineer*

The want of Tables of scantling for beams and trusses having been experienced in this department, the accompanying which are applicable to the most generally useful of the indigenous Mysore timbers, are now by desire of the officiating Chief Engineer, circulated for future adoption in all roof designs

With timbers differing so much in relative strength and elasticity, it would have been a tedious undertaking to frame a set of tables for each, a general and somewhat arbitrary classification has therefore been adopted, which within the limits assigned, will be found sufficiently accurate for all practical purposes, while at the same time allowing of one set of tables answering for all

From Table No I, it will be observed that the classification has been determined by the value of $E = \frac{L^3W}{bd^3\delta}$ in each case, class No I, embracing all timbers, the value of E for which has been found by experiment, to range from 4,000 to 4,500, class No II, those ranging from 3,500 to 4,000, and class No III from 3,000 to 3,500

Although arbitrary, this is a sufficiently near approximation to the truth, as an increase or decrease of 500 in the value of E, is very nearly represented by the difference of the scantlings, assigned to the spans next above and below

In using the Tables, first ascertain from No I, to what class the timber belongs, if of the first class, take out the required scantling directly

opposite the given span, whether for terraced or pent roofing, if of the second class, take the scantling assigned to the next greatest span, and if of the third class, take that of the next greatest again

Thus, if it be wished to ascertain the correct scantling of a teak wood girder for a terraced roof, 20 feet span, the girders being placed at 10 feet from centre to centre, take out the scantling under a span of 21 feet in Table No III, which gives 16″ × 11½″ Were on the other hand, the timber Sumpengee, or Poon, the scantling would be 16½″ × 11¾″, or that under a span of 22 feet, the timber being third class

It is not proposed here to explain the nature of the experiments undertaken for ascertaining the values of E for each timber, or give in detail the calculations made for fixing the scantlings required to sustain given weights of roofing, the following brief observations will therefore serve all present purposes

The formula employed is the ordinary one, $E = \frac{5}{8} \frac{L^3 W}{b d^3 \delta}$ for rectangular beams, (L) being clear length of beam in feet between supports, (W) weight in lbs of roofing spread equally along the beam, and determined by actual experiment for each description, (b) the breadth of beam in inches, (d) depth ditto, and (δ) the deflection assumed at 05 of an inch for every foot in length

Now if (a) be taken as the side of a square beam, and (W) be substituted for $\frac{5}{8}$ W, which is equivalent to the weight suspended from the centre, the above formula becomes $E = \frac{L^3 W}{a^4 \delta}$ hence $a = \sqrt[4]{\frac{L^3 W}{E \delta}}$

The value of E being given in this equation, for any known timber the side of a square beam capable of supporting the weight (W), with the deflection of $\frac{1}{20}$ of an inch to the foot, is easily found by logarithms

In calculating the present Tables, the value of E was taken throughout, as that given by the late Conductor Skinner, in his valuable work on Indian and Burman timbers, for Pegu teak, viz, 3,840, it will therefore be obvious that sufficient provision has been made for ordinary purposes, by transferring this and other timbers of equal strength, to the second class, or in other words assigning to them scantlings which would suffice for timbers, the elasticity of which is about 500 less than that ascertained by experiment

Having found the value of (a) for a square beam, an assumption has to be made, to ascertain the dimensions of a corresponding rectangular one

f a square to its diagonal, hence $d = b\sqrt{2}$ and as $a^4 = b\,d^3$. b

vely All the Tables have been calculated from the above formulæ

R H Sankey

Mysore Department Public Works

...ain, Color, &c	Remarks
red color fad- n, heavy, close le, an excellent sleepers, takes well, is not at- nts	This table gives the characteristics of the most generally useful timbers, for the Department in Mysore and Coorg, there are a great many others, however, which promise well, and should be employed as occasion offers, of these the following may be specially mentioned —
ose" or Black- n India, close xible, and dura- plish color It 3 years are re- ng	
sh brown color, le under water, re, and difficult ming the grain quires 12 to 15 is not touched ome consider it ing from a ha	
strong, durable ber, not very ght brown, is l building pur-	Others such as Mussay, Honnaul, and Genscena Murrah, procurable in Nugur, are also well reported on for all work, they have not, however, been identified botanically, or subjected to experiment

Synonyms		Classes corresponding to those in Table	Localities
Botanical	Canarese		
Diospyros melanoxylon	Raulay	Over standard of 1st class	Nugur
Conacarpus latifolia,	Dundugas		Kankanhylly
Vitex alata	Nowladdi	1st class,	Nugur
Acacia odaratissima,	Billawar,	2nd class	Nugur Coorg Kankauhully
Bassia longifolia	Ippa	3rd class	Nugur Coorg Kankauhully
Nauclea cordifolia	Yettaga,		Coorg Kankanhully & Astagram jungles
Azadarachta indica	Bavena,	,	Kankanhully & Maldan Talooka
Cedrela toona	Gundagurghy	4th class	Nugur
Vartica laciforma,	Jaloda	Unclassed,	Nugur Kankauhully
Ulmus integrifolia,	Tupiasco		Nugur

No XXVIII

MACHINES FOR RAISING WATER

(2ND ARTICLE)

Calculation of the Labor and Cost of Raising Water by different Machines occasionally (but not generally) employed in India BY SERGEANT J. WEBSTER, *Assistant Master, Thomason College*

6 WINDLASS AND BUCKET

(Worked by one man, with relief)

Water raised 4 feet

Content of bucket = 2 cubic feet = 12 5 gallons

Length of handle = 1 foot

Diameter of rollers = 15 and $7\frac{1}{2}$ inches

Velocity of handle per second = 2 feet.

Space passed through by the handle at one turn = 6 28 feet

Space passed through by the roller at one turn of the handle = 3 9 feet

Height to which the bucket must be raised = 7 8 feet

Therefore Number of turns required to raise the bucket = 2

Number of turns required to lower the bucket = 2

Time required for one turn of the handle $= \frac{6\ 28}{2} = 3\ 14$ seconds

Time required for four turns of the handle = 12·5 seconds

Time required for filling the bucket = 30 seconds.

Total time between each lift = 42 5 seconds

Number of lifts per minute = 1 4

Useful effect = 50 per cent

Discharge per hour = 1 4 × 60 × 2 × 5 = 84 cubic feet = 522 gallons

Estimated weight to be raised at each lift = 112 pounds

Ratio of power and weight = 1 3 2.

Modulus = 7

Required force to overcome the load $= \frac{112}{7 \times 3\ 2} = 50$ pounds

7 THE DALL

(Worked by two men, with relief)

Water raised 5 feet

Content of dall = 5 cubic feet

Using a leverage of 1 $1\frac{1}{2}$ and making one arm of the lever 8 feet, and the other 12 feet, we have—

Velocity of lever = 2 feet per second

Time required for raising the dall = $3\frac{3}{4}$ seconds

Time required for lowering the dall = 3 seconds

Time required for filling the dall = 30 seconds

Time required for emptying the dall = 5 seconds

Total time between each lift = 42 seconds

Number of lifts per minute $= \frac{60}{42} = 1\ 4.$

Useful effect = 70 per cent, we get—

Discharge per hour = 60 × 1 4 × 5 × 7 = 294 cubic feet = 1837 5 gallons

Estimated weight to be raised at each lift = 218 pounds.

Ratio of power and weight is = 1 1 5

Modulus = 9

Required force to overcome the load $\frac{218}{9 \times 1\ 5} = 161$ pounds

If two men are at work, each has a load of 80 pounds at every lift to overcome

8. THE DOUBLE PERSIAN WHEEL.

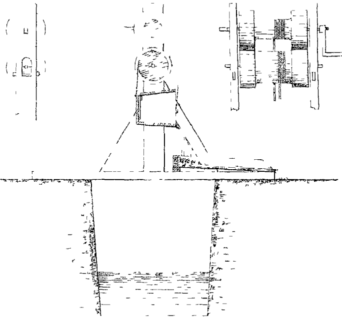
(One man and two bullocks employed)

Water raised 40 feet.

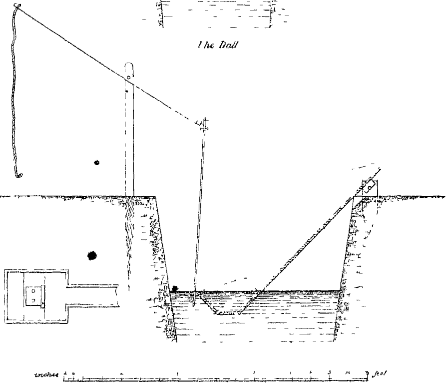
Proportion of gearing = 2 3.

MACHINES FOR RAISING WATER

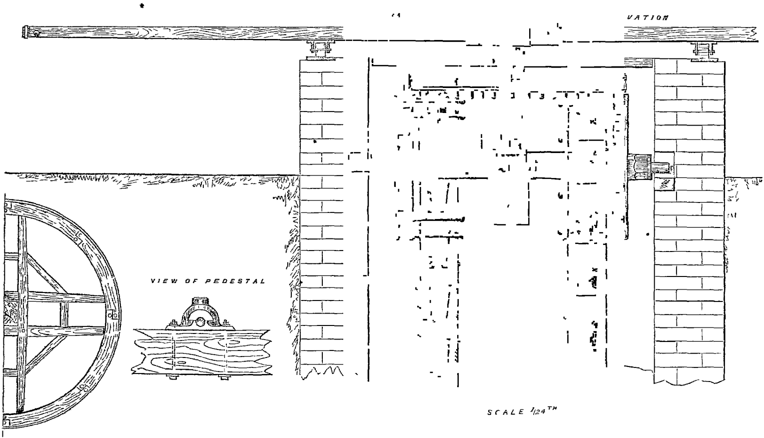
Windlass and bucket



The Dall



IMPROVED PERSIAN WHEEL



Diameter of driving wheel = 5 feet, pitch = 3 92 inches, cogs = 48

Diameter of bucket wheel = 3 feet 1 inches, pitch = 3 92 inches, staves = 32

At each turn of the bucket-wheel 8 buckets are emptied, the two wheels empty 24 buckets at each turn of the bullocks

Content of bucket = $\frac{1}{10}$ cubic foot

Therefore Discharge of water at each turn of the bullocks = $\frac{24}{10}$ = 2 4 cubic feet = 15 gallons

If the bullocks work on a level of 12 feet, the length of the bullock walk is = 24 π = 75 feet, and taking their speed at 2 miles an hour, we get—

Speed of bullocks per minute = $\frac{5280 \times 2}{60}$ = 176 feet.

Number of turns per minute = $\frac{176}{75}$ = 2 3

Useful effect= 60 per cent.

Discharge per minute = 2 3 × 2 4 × 6 = 3 3 cubic feet = 20 7 gallons.

Discharge per hour = 198 cubic feet = 1242 gallons

The buckets are 1 foot 3 inches apart, and the well being 40 feet deep, the requisite number of buckets for each wheel will be $\frac{40 \times 2}{1\frac{1}{3}}$ = 60, 30 being always full on each wheel, the weight of water on both wheels is = $\frac{60}{10}$ = 6 cubic feet = 375 pounds, which is the total weight to be raised, as the weight of the buckets and ropes are not taken into calculation, on account of their balancing each other

Space passed over by the weight at three revolutions of the bucket wheel = 10 π

Space passed over by the bullocks in two turns in same time = 48

Therefore Ratio of power and weight is = 10 48, or 1 4 8.

Taking the modulus of the machine at 5, we get—

Required traction = $\frac{375}{5 \times 4 8}$ = 156 pounds

If two bullocks are employed, each has a traction of 78 pounds to overcome.

9 The Suction Pump

(Worked by four men, with relief)

Water raised 25 feet.

Diameter of piston = 5 inches

Stroke of piston = 9 inches

Number of lifts per minute = 40

Quantity of water raised per lift $= \frac{25\,\pi}{4} \times 9 = 176\ 4$ cubic inches

Useful effect = 50 per cent

Quantity of water raised per minute = 2 cubic feet = 12 5 gallons

Discharge per hour = 120 cubic feet = 750 gallons

The load to be overcome in raising the piston

$$= 62\ 5\ \frac{\pi\,(\frac{5}{12})^2}{4} \times 25 \times 1\ 08 = 230 \text{ pounds,}$$

where 1 08 is a co-efficient for the passive resistances, as the friction of the water itself in the pump, the retardation of the water in its passage to the pump by the suction valves, and the weight of these valves

The pump is worked by a lever, in which the ratio of power and weight is = 1 3, and taking the modulus at 66, we get—

Required force to overcome the load $= \frac{230}{66 \times 3} = 116$ pounds

If four men are employed, each has a load of 29 pounds to overcome

10 Lift and Force Pump

(Worked by four men, with relief.)

Water raised 40 feet

Diameter of piston = 5 inches

Stroke of piston = 9 inches

Giving the piston an average velocity of 36 feet per minute, we get—

Number of back and forward strokes, or number of turns of the handle per minute = 24

Therefore Quantity of water raised at each turn of handle $= \frac{25\,\pi}{4} \times 9 \times 2 = 352{\cdot}8$ cubic inches

Useful effect = 60 per cent

Discharge per minute $= 352\ 8 \times 24 \times 60 = 5080\ 3$ cubic inches = 2 9 cubic feet = 18 gallons

Discharge per hour = 174 cubic feet = 1080 gallons.

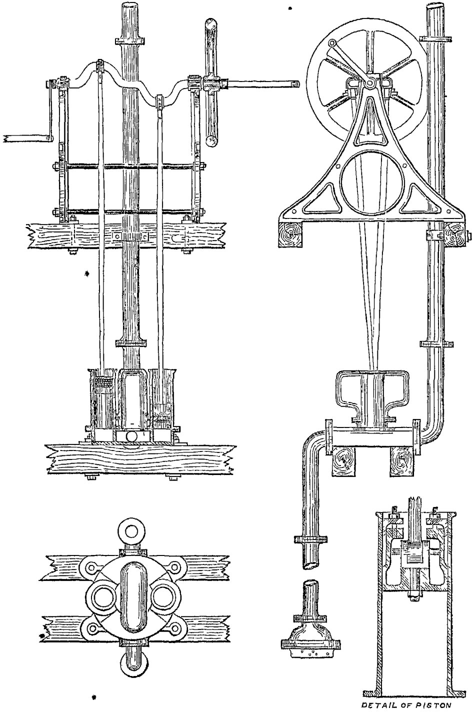
The load to be overcome in raising the piston is

$$= 62\ 5\ \frac{\pi\,(\frac{5}{12})^2}{4} \times 40 \times 1\ 08 = 368 \text{ pounds}$$

The length of handle being 15 inches, the ratio of power and weight

5-INCH SUCTION AND FORCE PUMP 9-INCH STROKE.

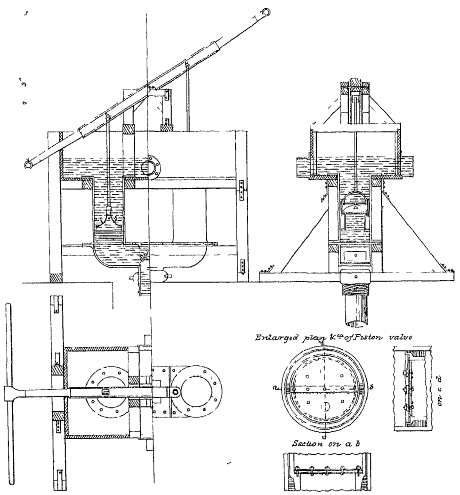
Scale 2 feet = 1 inch



MACHINES FOR RAISING WATER

5 in Suction pump

9 in Stroke



Scale 3/4 in - 1 foot

is = 1 5, and if the modulus be 66, we have—

Required force to overcome the load $= \frac{368}{66 \times 5} = 112$ pounds

If four men are employed, each has a load of 28 pounds to overcome

11 STREAM WHEEL

Water raised $5\frac{1}{2}$ feet

Length of floats = 6 feet, and depth = 2 feet

Number of floats = 10

Number of buckets = 15

Whole content of buckets = 5 6 cubic feet

Mean surface velocity of stream $= 2\frac{1}{2}$ feet per second

Revolutions of wheel per minute = 2 45

Velocity of wheel per second = 1 5 feet $= \frac{3}{5}$ths of velocity of stream

Dimensions of box with which the discharge was measured —

$\left.\begin{array}{l}\text{Breadth} = 18 \text{ inches,} \\ \text{Length} = 22 \text{ inches,} \\ \text{Depth} = 21 \text{ inches,}\end{array}\right\} = \text{content} = 4\ 8 \text{ cubic feet}$

Mean time required to fill the box = 30 seconds

Discharge per minute = 9 6 cubic feet = 60 gallons

Discharge per hour = 576 cubic feet = 3,500 gallons

Useful effect = 70 per cent.

Horse-power of wheel = 68

The above calculation is from actual measurement

12 WINDMILL APPLIED TO SUCTION PUMP

Water raised 20 feet

Assuming the velocity of the wind at 10 miles an hour, its velocity per minute will be = 879 feet

The concentrated force of the wind acts at a distance of 4 feet from the top of the sails, or 11 feet from the centre, that is, at the centre of gravity of the triangular sails. Now, the velocity of the sails at this distance, whether unloaded or loaded, so as to produce the maximum effect, should be nearly as great as the velocity of the wind, say $\frac{7}{8}$ths, and we get therefore

Velocity of sails per minute $= \frac{7}{8} \times 879 = 769$ feet.

Number of turns of wind shaft per minute $= \frac{769}{22\,\pi} =$ **11.**

There are two pumps of 10 inches diameter each, and the stroke is made to vary with the strength of the wind from 6 to 8, 10 and 12, inches, and taking 12 inches as the suitable stroke for the above mentioned velocity of the wind, and the useful effect of the pump at 60 per cent, we get

$$\text{Discharge at each turn of shaft} = \frac{10^2\pi}{4} \times 12 \times 2 \times 60$$
$$= 1{,}130 \text{ cubic inches}$$
$$\text{Discharge per minute} = 1{,}130 \times 11 = 12{,}430 \text{ cubic inches}$$
$$= 8\ 3 \text{ cubic feet} = 51\ 8 \text{ gallons}$$

Discharge per hour = 498 cubic feet = 3,108 gallons

Number of arms = 8, and their length = 15 feet each, the sails extend from the tip of the arm 12 feet towards the centre, and their length at the top is = 6 feet 3 inches

The force of the wind with the above-mentioned velocity is = 492 pounds per square foot, and assuming the effective area of the sails at 300 square feet, the total force acting upon the mill will be = 147 6 pounds, if the wind is perpendicular to the surface of the sails

Space passed through by this force at one revolution = 22 π feet

Space passed through by the piston at one revolution = 2 feet

Therefore Ratio of power and weight = 1 34 5, and taking the modulus at 5, we get—

$$\text{The load to be overcome in raising the piston} = \frac{62\ 5 \times (\frac{5}{6})^2\pi \times 20 \times 1\ 08}{4 \times 5}$$

= 1,458 pounds

The required force to overcome this load is only $= \frac{1458}{34\ 5} = 42\ 2$ pounds, which is equivalent to an impulse of ·14 pounds per square foot, and is in accordance with a velocity of the wind of about 5 miles per hour, from which it follows that the mill will not begin to turn until the wind reached nearly a velocity of 5 miles per hour Should it be desirable to let the mill work with a lesser velocity, it is necessary to reduce the stroke of the pump accordingly

With the velocity of 10 miles per hour, which we assumed in this case, the mill is able to overcome a load of 34 5 × 147 6 = 5,092 pounds, or more than three times the requisite one, which is to be accounted for by the fact, that the impulse of the wind increases as the square of the velocity.

TABLE SHOWING THE COMPARATIVE PERFORMANCE AND COST OF THE ABOVE MACHINES IN RAISING WATER TO THE SAME HEIGHT (40 FEET)

The expense of a laborer is put down at 2 annas and of a bullock at 4 annas per diem. Duration of work per diem = 8 hours

No	Methods	Stages	Useful effect per cent	Discharge per hour		Discharge per diem.		Ratio of discharges	Employs.		Daily expense	Quantity of water raised for one rupee.		Remarks
				Cubic feet	Gallons.	Cubic feet.	Gallons.		Men	Bullocks	Annas	Cubic feet	Gallons	
6	Windlass and bucket,	10	50	8 4	52 2	67 2	471 6	3	2		4	268 8	1670 4	Discharge increased with decrease of height.
7	Dall,	8	70	73	456	584	1840	2 6	4		8	1168	3680	Ditto
8	Double Persian Wheel,	1	60	198	1242	1704	9936	6 8	1	2	10	2534 4	15897 6	Discharge the same at any height.
9	Suction pump,	1 6	50	75	468·7	600	3748	2 67	8		16	600	3748	Discharge the same from 1 to 25 feet height
10	Lift and Force Pump,	1	60	174	1080	1392	8640	6 2	8		16	1392	8640	Discharge the same at any height.
11	Stream Wheel,	7 27	70	79 2	495	633 6	3960	2 8	Water					
12	Windmill applied to Suction pump,	2	60	249	1554	1992	12432	8 9	Wind.					

The cost and wear of the machines are not taken into consideration
No. 1, or the Beam and Bucket, is taken as unit for the ratio of discharges

J WEBSTER.

NOTE BY EDITOR

By a comparison of the Tabular Statements in this and the last No (II), and omitting the last two machines, of which the motive power is a variable and uncertain quantity, it will be seen that the Double Persian Wheel is the most effective as well as the most economical of any in the list These wheels may be seen at work at Lahore, and a small working model was exhibited at the Roorkee Agricultural Show, as well as models of the Windlass and Bucket, and the Dall The latter excited much attention from its extreme simplicity, and ought to answer well for short lifts

The drawings and calculations for the two pumps are merely given for the sake of comparison By employing horse or bullock gear to either, the power of course will be considerably increased, but it is doubtful whether any form of valve-pump, would be so effective and reliable for *continuous working* as the endless chain of buckets or the Persian Wheel, and up to a depth not exceeding 100 feet Beyond that depth the gearing is cumbrous and heavy in proportion to the weight lifted

Full sized specimens of Nos 11 and 12 were also exhibited at the Roorkee Show, and excited much interest The Stream Wheel is merely the old Chinese wheel, raising water from a running stream by its own force, and therefore self acting, costing nothing when once up, and not likely to get out of repair if protected from collision with boats, &c It can, however, only be effectively employed in a stream running with some velocity and wide enough for the wheel not to interfere with navigation, but its simplicity and economy recommend it where the other conditions are favorable The wheel exhibited was 10 feet in diameter, and cost Rs 200, but ought to be built entirely of iron at a less price than that

The Windmill was made at the Roorkee Workshops for the purpose of raising water for filling a swimming bath at Meerut, and seems likely to answer well Considering the cheapness of the motive power, and that the wind blows steadily nearly all the year from one quarter or another in the Upper Provinces, it is curious that so little use is made of it as a prime mover A few desultory attempts have I believe been made, but not properly persevered with

If any correspondents will furnish descriptions and calculations similar to the above for any other water-raising machines used in other parts of India, I shall be glad to publish them.

J G. M

No XXIX

NORTH WESTERN PROVINCES IRRIGATION REPORT, 1861-62

[The following is an Abstract of the Revenue Report, prepared by the Irrigation Department for 1861-62, *but only just printed.]*

The totals of the Canal Revenues for the past year were as follows —

North Western Provinces	Ganges Canal,	Rs	7,05,800 9 3	
	Eastern Jumna Canal,	„	2,50,531 11 1	
	Doon Canals,	„	16,011 4 8	
	Rohilcund Canals,	„	35,533 6 9	
	Agra Irrigation Works,	„	12,698 9 0	10,20,575 8 9
Punjab	Western Jumna Canals,	„	4,03,968 15 6	
	Delhi and Goorgaon Irrigation Works,	„	18,790 0 0	4,22,758 15 6
	Grand Total, Rupees,			14,43,334 8 3

The total cost of maintenance and repairs for the same period was—

North Western Provinces	Ganges Canal,	Rs	4,79,161 2 8	
	Eastern Jumna Canal,	„	1,03,389 6 7	
	Doon Canals,	„	22,543 2 10	
	Rohilcund Canals,	„	25,488 5 2	
	Agra Irrigation Works,	„	11,589 4 0	6,42,171 5 3
Punjab	Western Jumna Canals,	„	2,13,577 11 2	
	Delhi and Goorgaon Irrigation Works,	„	1,962 12 2	2,15,540 7 4
	Grand Total, Rupees,			8,57,711 12 7

From the foregoing we find that the balance at credit of Receipts over Expenditure for the works of Irrigation in the North West Provinces, amounted to Rs 3,78,711-3-6, and including the Punjab works, to Rs 5,85,104-11-8

Ganges Canal

The subjoined details exhibit in a brief form, some useful information, regarding the present state of the Ganges Canal

Length of main Canal and two terminal divisions, ...	Miles,	520		
Length of Futtehgurh branch (in progress),	„	83		
Length of Boolundshuhur branch, including right and left branches (in progress),	„	46		
Length of completed rajbuhas to 30th April, 1862,	„	1,921		
Number of villages which received the benefits of irrigation,	No	3,982		
Area of land irrigated,	Square miles,	581		
Cost of main Canal, including the two terminal divisions, up to 30th April, 1862,	Rs	1,60,58,135	9	1
Cost of Futtehgurh, Boolundshuhur, and Koel branches up to 30th April, 1862, ...	„	6,86,318	2	3
Cost of rajbuhas up to 30th April, 1862,	„	27,95,270	2	9
Total cost of Ganges Canal up to 30th April, 1862,		1,95,39,723	14	1
Value of crops produced by Canal during 1861-62,		1,22,46,875	13	11
Cost of maintenance and repairs,		4,79,161	2	8
Amount of revenue,		7,05,800	9	3

Deducting the cost of maintenance and repairs from the amount of revenue, it will be observed, that a balance of Rs 2,26,639 appears, or a surplus nearly equal in amount to that of last year, when for the first time, the Ganges Canal paid its own expenses of establishment and repairs, and yielded a money return to the Government

It is gratifying then to note that the surplus of the present year is as great as that of its predecessor, and that the Canal revenue, to which an unnatural stimulus was given in *1860-61*, still indicates progressive improvement

In the *Northern Division*, as must always occur, the most work has been done, as here are situated the most important engineering works on the Canal, which require constant and careful supervision and necessitate extensive repairs, these works had to undergo a very severe trial owing to the heavy rainy season The bunds which are annually thrown

across the Ganges at the close of the rains in order to ensure a full supply to the Canal, are situate in this division, and are works of considerable magnitude, the principal of these bunds was breached on the 17th May, an unusually early date, in consequence of the almost unprecedented early commencement of the rainy season, this led to an immediate fall in the Canal supply, and on the 20th June, the total rupture of the bund took place, owing, however, to the precautions taken in strengthening the bund across the Hurdwar channel, the supply required was maintained without inconvenience

The boulder bunds or temporary weirs constructed at the head of the Canal to admit of the supply being sent down, were four in number

No 1 —Bund across the Neel-Dharra channel of the Ganges

,, 2 —Beemgoda Bund, across the main branch of the Ganges

,, 3 —Beemgoda Bund in rear of above

,, 4 —Bund across the Hurdwar channel.

The work in these bunds is commenced with triangular cribs or boxes made of young sâl trees, measuring from 18 to 20 feet in length These cribs are floated to the site of the bund, loaded with boulders and sunk to the bed of the river; the bund is then formed by filling the boxes with boulders, its face being protected with small stone and gravel, and the whole covered with thick grass mats, to reduce the leakage as much as possible

The protective works in both the Puttree and Rampoor Raos, have, notwithstanding the severity of the floods, stood their test well Mr Login states that, in consequence of the approach of the latter on to the superpassage in an oblique direction, he constructed spurs similar to those at the Puttree, which turned its course perpendicularly to the Canal

Regarding the effect of the spurs in both of these rivers, Mr Login observes that, the fan of sand which has from year to year extended itself down the Puttree valley, has at last reached the works, and there is now 18 inches of sand on the flooring of the superpassage, while on that of the Rampoor the sand is 7 feet deep, below the Puttree works, the Canal is in pretty good order, though the bed has considerably deepened

Mr Login also remarks that the River Rutmoo has silted up considerably above the Canal, while below it, the retrogression of bed level is in progress, and as the crib-work at the tail of the Dhunowri dam

is becoming decayed, he considers that it should be replaced by boulder masonry

Mr Login has lately adopted the plan of never entirely closing the Dhunowrr regulating bridge during high floods, but of always keeping up a 3-feet supply in the Canal, which he considers will operate beneficially, not only in saving the revetment walls of the Solani aqueduct, from unequal and changing pressures, but in restoring the bed of the earthen aqueduct to its proper level by the deposits of silt, held in suspension by the flood waters, and also in keeping up a somewhat uniform supply in the Canal during the rains

The *Upper Central Division*, commences at Jaoli, and extends from the 51st to the 84th mile of the main Canal The head of the Futtehgurh branch is likewise situated at Jaoli, and the works on the branch, together with those in the Upper Central Division of the Canal, were superintended to the close of the official year 1861-62, by the same Officer

The Futtehgurh branch is in course of excavation down to its 83rd mile, the first 40 miles were excavated previous to the mutiny, and the masonry works completed at the same time, another portion, 20 miles in length was also commenced, and work was in progress when it was suspended by the mutiny in 1857, but, it has since been completed The remaining 23 miles were commenced last year as a famine relief work, and are nearly excavated, so that we may consider the excavation as far as the 83rd mile to be complete

Two escape channels have been designed for the branch, one at Shajehanpoor and the other at its terminus, near Makhena, at the 83rd mile the head of the Shajehanpoor escape is nearly complete, and the channel has been excavated, but the Makhena escape has not yet been commenced

The total increase of revenue in this division is satisfactory and creditable to Mr Parker, the increase in the khureef is very large indeed, and so would in all probability have been that of the rubbee, had it not been for the constant presence of clouds, and the generally damp season, which led the Zemindars to expect a plentiful fall of rain, and therefore induced them to put off as much as possible the irrigation of their fields

In the *Lower Central Division* also, the abundant rainy season was un-

favorable to the prospects of the Canal, not only was a large khureef crop secured without the use of artificial irrigation, but the ground was left in such a moist state from the plentiful rainfall, that the Zemindars were enabled to plough and sow without further waterings In spite, however, of circumstances so adverse to Canal interests, it is gratifying to observe that the revenue has shown favorably in comparison with that of the preceding year, which being one of drought and famine, might be supposed to have been exceptionally high Ensign Willcocks, the Superintendent of this Division, also remarks on the very large and steady increase of the better description of crops, such as sugar-cane and indigo, both of which were almost unknown in this part of the country until the Canal afforded means for their cultivation, he also observes that, "when I first joined the Ganges Canal I certainly took a gloomy view of its prospects, but now I am as sanguine of its prosperity, as those who have had a much longer experience of it than I have had, and I look forward to an early date, when my own division will return, in ordinary seasons, from 3 to 3½ lacs of rupees," this remark from an Officer of such experience in the Irrigation Department is most valuable

In order to illustrate the amount of benefit derived by the country from the construction of the Canal, in allowing of the cultivation of the more valuable description of crops, Ensign Willcocks states, "that to his knowledge 10 beegahs of sugar-cane were sold in one village for 960 rupees," and he observes that the Meerut district appears peculiarly favorable to this cultivation Ensign Willcocks also remarks upon the great number of indigo factories which are being constructed in all directions in the Boolundshuhur and Allyghur districts, and in fact, wherever Canal irrigation gives a fair promise of success

Cawnpore Division —The revenue in this division has made a very satisfactory advance in spite of the abundant rainy season, which is the more gratifying as it has been principally made in rajbuhas already in existence, and is not much due to the opening out of new lines

During the year a syphon has been constructed under the Canal, near the village of Manawa, to provide for the surface drainage of the country The work was executed under considerable difficulties on account of the depth at which it was necessary to carry the foundation below the Canal bed, and with a full supply running within a few feet of its site

The want of a dock at Cawnpore, has for some time past been much felt,

as the channel there is very contracted, and the numerous boats which ply up and down the Canal, are laden and unladen along its banks, the work has been commenced this year

A water-course for the memorial garden at Cawnpore, has also been commenced under the orders of His Honor the Lieutenant Governor North Western Provinces This will greatly improve the garden, and by flushing the drains in the city itself, tend much to the comfort and cleanliness of the townspeople

Mr Anderson brings to notice the large annual expenditure on silt clearance in this Division During 1861-62, the silt taken out from his rajbuhas amounted to no less than 120 lacs of cubic feet, at a cost of Rs 13,500 The silt is, however, peculiarly valuable for strengthening the banks, where the rajbuhas run, as they do chiefly, through Oosur land, in this division

Etawah Division —The increase of irrigation, amounting to 50 per cent in excess of that of the previous year, is very satisfactory, and the more so as it has been almost entirely obtained from old standing lines of irrigation, no new ones having been opened till nearly the end of the year, and then, not in time to afford much aid to the country This branch, as also that of Cawnpore, compare very disadvantageously with the remainder of the Canal, as owing to the unfinished state of their rajbuhas, they are unable to utilize the supply to which they are entitled, though at the same time, they require their full supply in order to obtain the necessary level of water surface to admit of free irrigation, the consequence is that the water is necessarily thrown away at points where the Canal contracts in width, and escape channels are situate, this state of things, however, it is hoped will shortly be remedied, as every endeavour is being made to complete the rajbuha channels, many of them being actually in course of construction, and others, under survey and examination

The length of this division is 170 miles, in addition to that of completed rajbuhas of 311 miles Excavation at the tail of this branch has been in progress during the year, but the terminal masonry works have not yet been commenced

Boolundshuhur Branch—The construction of this line, of which the first 6 miles were excavated before the Ganges Canal was opened, was sanctioned by the Government N W Provinces, early in the year 1861, and formed one of the works specially undertaken during the

recent famine, for the relief of the starving population of the Provinces

After a brief but careful survey of the country lying beyond the already completed portion of the branch, employment was given during the month of March 1861, to the famine stricken people, who were sent from the neighbouring districts in great numbers, by putting them on the prolongation of the original work. Those who were too weak to excavate, were employed on light work, as repairing banks, clearing jungle, &c, but after a time, these weakly gangs diminished rapidly. The nature of the soil, however, in which the several parties worked was such, that the rates, which were occasionally high, were affected far more by it, than by the physical condition of the people, which was generally good and certainly improved with the progress of the work

EASTERN JUMNA CANAL

The total revenue for the year (given in detail below) amounted to Rupees 2,50,531 65, and the total cost of maintenance for the same period to Rupees 1,03,389 11, leaving a balance of income for the year of Rupees 1,47,142 24

An average of areas of the several kinds of crops irrigated taken from the returns of the past four years may be interesting

Nature of Crops	Average, acres	Per Centage
Sugar-cane,	26,341 90	12 05
Rice,	38,132 79	17 45
Indian Corn,	8,295 29	3 80
Wheat and Oats,	97,915 98	44 82
Inferior Grains,	33,971 36	15 54
Cotton,	5,750 31	2 63
Indigo,	508 57	0 23
Orchards and Gardens,	4,218 16	1 93
Grasses,	856 18	0 39
Insufficiently Irrigated,	2,542 63	1 16
Totals,	2,18,533 47	100 00

Feeling the desirability of obtaining reliable data for estimating areas irrigable per cubic foot, per second, in each Fussil, Major Brownlow has given the mean discharge of Canal, and areas irrigated in each Fussil, and during the whole year for the last four years, and from the averages obtained, he thinks we are fully justified in assuming 70 acres as the

area irrigable during the *khureef*, 130 acres during the *rubbee*, and 200 acres during the whole year, per cubic foot, per second The mean discharges have been most carefully calculated, and the slight discrepancies observable in the final result arise from the utter impossibility of exactly separating the periods of khureef and rubbee irrigation

	Khureef	Rubbee	Whole year
Mean discharge of Canal,	1,212 50	938 50	1,061 25
Areas irrigated,	86,180 46	1,32,353 01	2,18,533 47
Acres irrigated,	71 05	140 04	205 93

Major Brownlow says,—"A comparison of results obtained from the data given above with those furnished by Colonel Rundall, Madras Engineers, in a late letter to Government, will show that the Irrigation Works of the North Western Provinces will bear a comparison with those of Madras The total cost of construction of this Canal up to commencement of current year, amounted in round numbers to Rs 14,13,500 The maximum area hitherto irrigated is 2,60,000 acres The average area of the past four years is 2,18,533 acres, the average water-rate for the same period being Rs 2,27,835 The average annual cost of establishment is Rs 52,000, of repairs, 44,000 Total, 96,000 From these we deduce the cost of construction as Rs 5 4 per acre of maximum, and Rs. 6 5 per acre of average area irrigated during the past four years, while the maintenance and establishment amount to 7 annas per acre of average area The Madras rates, given by Colonel Rundall, are, respectively Rs 6 and 8 3 per acre as cost of construction and 6 6, annas per acre to cost of maintenance Colonel Rundall gives the Madras cost of maintenance, repairs, and establishment as 7 per cent on first cost of construction, ours amounts to 6 8 per cent The Madras per centage of maintenance on water-rate is 14, (2,50,000, on a total water-rate of 18,00,000,) ours is 42, but it must be remembered that the Madras water-rate per acre is just treble ours (being Rs 3, while our average is only 1 04 per acre), and that reduced to our standard of charge, then per centage of maintenance on water-rate would be just equal to ours Colonel Rundall appears to think that no fair comparison can be instituted between the Irrigation Works of the North

Western Provinces and of the Madras Deltas, as the latter not only afford irrigation, but combine therewith a system of river embankments for protection from floods, drainage channels, and navigation Canals. But if these works were absolutely necessary and primarily intended for the completion of the irrigation system, the fact of their sub-serving other purposes does not invalidate the comparison between them and our own, as far as irrigation results are alone concerned, although, of course, it adds largely to the indirect value of the Madras Works."

The floods during the past rainy season have been unusually heavy. The Khara and Fyzabad Heads have been blocked up more than usual with shingle and boulders, at the latter not a trace remains of a large and deep channel, through which the main supply of Canal was drawn. The Khara Head fared somewhat better, and by the aid of spurs afforded the full supply required. The rapid in the main Jumna, just below the mouth of the Khara head channel, has retrograded considerably, and the crest of it will in a few years pass the head, rendering a deepening of its channel necessary.

The Fyzabad dam flooring has been much scoured and cut up, but on the whole, the work has escaped very well. A couple of gates and some planks were washed away by the floods, and the apparatus was somewhat injured.

The Nyashuhur weir suffered most severely, having been cut through at short intervals along the whole of its length, and the brick-on-edge facing has been torn off by the boulders and trunks of trees that scraped over it during the rains. The section of this weir is very slight considering the heavy and constant floods to which it is exposed, and at some future date it should certainly be strengthened. The apparatus of sluices and regulators suffered considerable injury, and the spur separating the Bhoodee Jumna from the sluice channel, was entirely carried away during the tremendous floods that came down between the 18th and 20th July, and 8th and 10th of August. The first topped the roadway of the sluices, carrying away the railings fixed along the sides of it, and measured seven feet in depth on the weir sill. The second buried all the masonry works at the place, except the Regulating bridge, under water, for some hours, smashed one of the gates, and was within a very little of forcing its way into the canal. To prevent the recurrence of such a catastrophe, an estimate for a

new regulating bridge was submitted and sanctioned by Government, and the foundations and floorings laid by the end of April 1862

Major Brownlow thus explains how the money goes on repairs of torrent works, in three months, he had on nine several occasions, really heavy and dangerous floods raging simultaneously over every dam and weir in the Northern division, none of them discharging less than 10,000 cubic feet per second, and many of the Jumna floods ranging up to treble and quadruple that volume In the above statement no account is taken of ordinary light floods with discharges of 4,000 and 5,000 cubic feet per second, which quantity of water passes pretty steadily over the Nyashuhur weir during the entire rainy season

The expenditure incurred in restoring the head works of the Eastern Jumna Canal, enumerated in the foregoing paragraph, and keeping the other masonry works together with the Canal banks and roadway in an efficient state of repair, amounted during the year to no less than Rs. 44,122-6-10

Lastly, operations have been carried on in the Sultanpore swamp Drainage cuts were steadily pushed on through the heart of the old swamp for an aggregate length of six and a-half miles, while lateral cuts were excavated from the main channel tapping the worst parts of it, and leaving but a very small portion unculturable

These drainage operations I am happy to say have been eminently successful At the close of the last rainy season, luxuriant rice was growing in places where four feet of water used to stand all the year round, and land that formerly would not even produce rice was being broken up for wheat

The financial state of this Canal is fast approaching to a most satisfactory one At the close of last year the balance of the charges over the income amounted to Rs 1,28,740-6-1, and this sum has been reduced during the present year to 52,273-4-4, the expenditure being for the current year 1,03,389-6-7, including all charges, against a revenue of 2,50,531-11-1, showing a rate of profit for the year upon the capital, viz, of 14,20,720, or 10 3 per cent Next year it is hoped that the balance of charges over the income will be very small, and that at the close of the following year the balance of the income will exceed that of the charges, i e., the Canal will have paid up the whole cost of maintenance and repairs, plus five per cent. interest on the capital, into the

Government Treasury, and leave a balance in hand at the credit of Government

DOON CANALS

The peculiar circumstances attending the Doon Canals, inasmuch as they are meant to supply water not only for irrigation but for drinking purposes, when it could not be obtained by any other means have been dwelt on before, and Mr Forrest remarks thus on their peculiarity of construction —"There are also peculiarities in their construction which it may be needful to point out as bearing on their heavy original cost and heavy charges for repairs afterwards, and the fluctuations in the revenue from them With a small section and carrying but a small quantity of water, they have heavy and dangerous works on them, arising from the nature of the country in which they are constructed They have to wind round hill sides, pass over wide and deep ravines and cross rapid mountain torrents The Beejapoor water-course runs for a long distance along the face of a perpendicular cliff, the channel being partially let into the living rock The Kutta Putthur Canal is exposed for half a mile to the direct attacks of the Jumna river, immediately on its rush forth from the Himalayas, has then to cross a dangerous hill drainage line, its masonry channel runs for three miles along the edge of an almost perpendicular bank, exposed in many parts to the attacks of water below, and it crosses deep and wide ravines, by means of three arches of 50 feet span each, two of 30 feet span, and long embankments Towards its tail it has an embanked channel, in some places 20 feet high, more than 1,000 feet in length, in which are four aqueducts, one of which has two openings of 50 feet span each The Kallunga Canal has on a very short space of its length three aqueducts of 30 feet span each, and one of 50 feet span The water crossing the latter, runs 30 feet above the bed of the stream below" Colonel Morton, in his Report for 1858-59, described these works as "of gigantic size, compared with the capacity of the channel The masonry channel of the Jakhun Canal winds four miles round a hill side, and in many places seems to hang in the air 500 feet above the bed of the river below All these works are subject to the attacks of the mountain torrents running down slopes of 3 feet or 4 feet per 100 feet, and swollen by showers of rain, which throw down 5 or 6 inches in as many hours By all the points of attack being gradually

discovered and guarded against, and works of bad construction being removed, the works are in time rendered perfectly safe, though constant vigilance and instant repairs are always necessary There has not been a day's interruption in the supply of the Beejapoor Canal for the past five years And in time, all the Canals will come to that, but in the meanwhile they have to bear heavy expenses and the Revenue meets with unexpected checks "

THE FOLLOWING IS THE ABSTRACT OF INCOME AND EXPENDITURE FOR THE YEAR

	Expenditure			Income			Profit			Loss		
	RS	A	P	RS	A	P	RS	A	P	RS	A	P
Beejapoor,	3,816	1	9	7,056	5	1	3,210	3	4			
Rajpoor,	5,107	0	10	6,712	15	11	1,605	15	1			
Kutta Putthur,	8,389	8	8	1,503	3	5				6,886	5	3
Kallunga,	5,200	7	7	738	12	3				4,461	11	4
Total,	22,543	2	10	16,011	4	8	4,816	2	5	11,348	0	7
Net Loss,										6,531	14	2

Two water-courses are therefore unproductive, and their unproductiveness eats up the productiveness of the others But the Kallunga Canal is only just beginning to irrigate, and the Kutta Putthur Canal, after a long period of unproductiveness, is rapidly and steadily increasing its revenue, doubling it each year, for some three or four years back, so that there is every reason to hope that it will not be long ere this excess of expenditure over income will be caught up, and the balance be in favor of the latter As both the Kutta Putthur Canal and the Kallunga Canal, discharge more water than the Beejapoor Canal, the revenue from them ought at least to equal that from the latter, and that being the case the total revenue would amount to nearly 30 000 rupees, and the balance of income over expenditure be a large one The above then, the works constructed being taken as stock in hand, equal to the capital sunk, is the charge of the Doon Canals to the Government The indirect advantages of these Canals to the people and to the Government have been sufficiently dwelt on before

Mr Forrest notices a striking instance of the indirect advantage to the Government from these works of irrigation on the Jelhun Canal, he says, "the masonry channels having now reached to the edge of the forest lands, numerous applications have been sent in for the purchase of the latter Looking at the map of these lands, it will be observed how often is marked, 'site of village,' such site being only now distinguished by a group of mango trees and grass grown tanks The former settlers could not provide drinking water for themselves, or their cattle, and gave up the ineffectual struggle to redeem the wilderness"

In my Report for last year, I mentioned the large increase that had taken place in the irrigation and revenue owing to the failure of rain during the famine year The return for the rubbee of 1860-61 was nearly $2\frac{1}{2}$ times more on the Beejapore Canal, twice as much on the Rajpore Canal, and $4\frac{1}{2}$ times as much on the Kutta Putthur Canal, as in the corresponding season of 1859-60 It is interesting to remark that though the famine year has passed away, the revenue it called forth has not fallen back It ever seems to be the case on these occasions that the people being forced into taking water by the pressure of the season, find its benefits, and continue to take it The following table shows at once that a permanent impetus was given in 1860-61, to the Canal revenue —

	RS	A	P
1859 60,	12,308	0	3
1860-61,	14,923	4	7
1861 62,	16,011	4	8

The above facts point to the increasing prosperity of the Doon Settlement

Rohilkund Canals

The irrigation works in Rohilkund, under the direct control of this Department, are confined to four rivers, viz, the Kylas, East Bygool, Kitcha and Dhora, and Paha, from which the Rohilkund canals or water-courses derive their names

Kylas Canal—This canal is only in course of construction, and is not yet available for irrigation, its head is situated near the village of Byranee, about six miles above the junction of the Deoha with the Kylas, where a masonry dam having 15 openings of 9 feet each, has

been constructed across the latter river, this dam is built on the ordinary plan, having piers eight feet in height, the openings between them being fitted with gates and planks, the foundations have been sunk to a depth of 13 feet, and its flooring is on a level with the river's bed On the right flank the canal is taken off by a masonry head of two openings 8 feet each, the floor being raised 2 feet above that of the dam

The Kylas canal has a bottom width of 15 feet, and is calculated to carry 150 cubic feet per second, it is 9 miles in length, along the whole course of which excavation has been commenced and about one half completed For the first seven miles the digging is very deep, varying from 12 to 20 feet in depth, and as the spring level of water is found at an average depth of 6 feet, considerable difficulty exists in carrying on the work

At the village of Dhoondree, the main line divides into two, called the east and west branches, the former will be 15 miles in length, of which 11 have been excavated, with a bottom width of 8 feet, it runs along the watershed between the Upserrie Nuddee and the Deoha, and is intended to irrigate the tract lying between these streams The west branch is to be of the same width as the east, but reduced to 10 miles in length, and of this about 1 mile only has been excavated, it will cross the Upserria Nuddee, close to the village of Dhoondree by a masonry aqueduct, and run along the watershed between that stream and the Pungheelee Nuddee

East Bygool Canal—The construction of the east and west Gerem Branches, and the prolongation of those issuing from the Oogunpoor Partitem, form the only new works on the East Bygool, and these were undertaken to afford employment to the starving poor in Rohilkund

The Gerem Branches are taken off from either flank of the Gerem dam, and have each a bottom width of 10 feet at their heads, gradually decreasing to 6 feet, with a discharge of 40 cubic feet per second The east branch will be $8\frac{1}{2}$ miles in length, of which about three-fourths are out of hand, and the west 10 miles, which are quite complete. The upper 5 miles of the west, and about $1\frac{1}{2}$ miles of the east branches have, however, only been in operation during the past rubbee season

The total area irrigated was 5,61,160 local Beeghas, or 1,40,290

standard Beegahs = 137 square miles The total water-rate charged upon the above was rupees 33,032-8-0 giving an average charge of 3 annas and 9 pies per standard Beegah

The income for the year 1861-62, was as follows —

	RS	A	P
Water rent,	33,032	8	0
Sale of produce, sundry collections, &c,	2,500	14	9
Total,	35,533	6	9

The working expenses amounted to rupees 25,488-5-2, showing a balance in favor of the income of rupees 10,045-1-7, and giving a rate of profit for the year upon entire capital of 4 7 per cent

[*A notice of the Agra Irrigation Works will appear in a future number*]

NOTE BY EDITOR

SEEING that much uneasiness has been lately felt as to the state and prospects of the Ganges Canal, and that many have been even in a hurry to pronounce it a "failure," the data of the above report (the last one issued), cannot but be considered as very *satisfactory* The returns for the past year, which are now *being made up*, are, I understand, still more favorable, showing a return from water-rent of nearly 10 lakhs of rupees on this one Canal

The fact is, (paradoxical as it may appear,) that it is the *complete success* of the work which has been the great difficulty of the Irrigation Officers So rapidly and completely has the Canal become bound up with the agricultural prosperity of the Doab, that a few weeks' closure for the purpose of executing repairs, causes a loud outcry, and a serious loss both to Government and the people Like most other great works, defects have been discovered in the original construction, which did not show themselves at first when they could have easily been remedied, and the state of some of the masonry works below Roorkee has become dangerous, not from error of design but from faulty construction If the Canal could be closed for six months this could be easily remedied, but as that is to be avoided if possible, the work of repair has to be done bit by bit as it best can, and under circumstances which naturally cause much anxiety to all concerned

It is difficult to avoid some reference to the controversy which, has now to a great extent, at least been made public, between Sir Arthur Cotton and Sir Proby Cautley, on the defects alleged by the former to exist in the original design of the Canal, while the great weight justly attached to any opinion of General Cotton's on such a subject, and the difficulty of understanding the points at issue without maps and plans and elaborate explanations, makes it impossible to do full justice to either side of the argument in a short note In a future number the whole controversy may perhaps be placed before the reader It may suffice here to offer a few remarks on the

two main points at issue —1, The excessive slope of the bed 2, The position of the head of the Canal

As regards the 1st, it is called a minor objection by Sir Arthur Cotton, but is admitted by Sir Proby Cautley himself, to be the one great mistake he made That the slope is too great for such a depth of water, and in such a soil, no engineer will now deny, but as the reduction of it would have necessitated double the present number of falls and locks, it would have amounted to a practical stoppage to Navigation, which General Cotton evidently considers to be as important as Irrigation

As to the 2nd point, it is allowed on all sides, that no choice remained between that of the present site for the head, and that of a weir or series of weirs across the sandy bed of the Ganges lower down That no objection exists on the part of the Canal Engineers to the employment of weirs, will appear from the fact that a project for a masonry weir across the Ganges at the present head (Hurdwar), was sent up more than two years ago, and is still before Government But the bed of the river there is shingle, not sand, and weirs across sandy beds have no doubt been strongly objected to by engineers in Upper India, as works which, however well adapted to a Delta are inapplicable to a Doab A Delta is a tract of low alluvial country below the bifurcation of a river, whose bed is raised above the level of the surrounding ground from the deposits of silt thrown down A dam of very small height across such a river, with cuttings through the lip of the channel on both sides, will evidently give great facilities for irrigation

A Doab is a tract of high table land (the *Bangur*), between two rivers, which run in narrow beds (the *Khadir*), considerably depressed below the high land, from which indeed they are generally separated by a steep bank from 30 to 150 feet high A weir across such a river must extend across the whole valley from 3 to 8 miles wide, and must either be of such a height as to flood the whole country above, and be altogether impracticable in construction , or, if not a moderate height, the water can only reach the high land by long and *deep* cuttings, through a sandy subsoil and below the level of the springs, along the whole course of which surface irrigation would be impossible

One other point may be noticed , there is no system of irrigation extant in India, so far as I am aware, whether the Canal system of the N W Provinces and the Punjab , the Anicut system of Madras , or, the Tank system of Central India, which is simply an improvement on the old native system in use almost from time immemorial Doubtless, the improvement has been great, but the leading idea had been first seized upon by our native predecessors It this be so, and as there are no remains of weirs across any of these rivers, it is, I think, strong presumptive evidence against their applicability to this part of the country It is easy to say that the experiment should be made, but the experiment would prove nothing unless carried out on a grand scale and at a vast expense, and if unsuccessful the experimenter would be placed in a very unenviable position —

J G M

No XXX

IRON SUSPENSION BRIDGE OVER THE BEOSI RIVER— NEAR SAUGUR.

(Re-printed from the Journal of the Asiatic Society for 1833.)

We take peculiar pleasure in bringing to the notice of our readers the completion of this work of art, because it has been constructed entirely out of the resources of the country, and being the first attempt at such an adaptation of native material and native workmanship, more than ordinary credit is due to the skilful Engineer who planned and executed it, and who, moreover, from his long residence in India, could have acquired only a theoretical acquaintance with the system of suspension bridges introduced within these few years, and now so rapidly spreading in Europe

The bridge was erected at the suggestion of T H Maddock, Esq, agent to the Governor General in the Ságar and Nerbuda territories, upon the plans and under the sole superintendence of Major Duncan Presgrave, mint and assay-master at Ságar

Engineers in Europe, accustomed to find everything provided to their wants, can have little idea of the personal labor which devolves upon their brethren of the craft in this country, where to the duties of architect and draughtsman are not only added those of builder and overseer, but the whole of the subordinate trades of the brick-maker, mason, carpenter, and iron-manufacturer, in a climate too where a trifling exertion produces exhaustion, and incautious exposure, fever or death, and where the tools must be made and the hands that employ them instructed *ab initio* We will not say that the native mistrees and laborers are not

capable of learning or of working well, especially in Upper Hindustan; the bridge before us is a sufficient refutation of that common and indolent remark but all will agree that a peculiar talent is requisite to manage, instruct, and drill them, and this faculty is possessed by Major Presgrave in an extraordinary degree The secret of his influence may be easily traced—he is a workman himself he wields the hammer, makes and works the lathe, surveys the ground, searches the mines, smelts the ore, and has all the skill of contriving with the simplest means,* for which the people of this country are themselves so conspicuous

The Ságar bridge may indeed be called an experiment to try the resources of the country—to see whether the iron could be manufactured into bars of a quality fit for bridges,—and whether these bridges could be made by native workman who had never wrought or even seen iron of the dimensions required The question has been satisfactorily answered, and even in point of economy, notwithstanding the numberless extra expenses incident to a first undertaking, and the distance, eleven miles, of the work from the yard at Ságar the bridge has been pronounced cheaper than those in Calcutta made with English materials, while of its design and execution no higher encomium can be given than the assurance of the visiting Engineer, Major Irvine, that he had seen nothing superior to it in Europe The Governor General is stated to have expressed equal satisfaction after inspection, and only to have regretted that so noble a bridge should be wasted upon so remote a locality!

We have with permission taken a reduced copy of the elevation and plan, lithographed by M Tassin, to accompany a private Memoir of the Beosi bridge The latter authentic source supplies us with the following particulars of the works

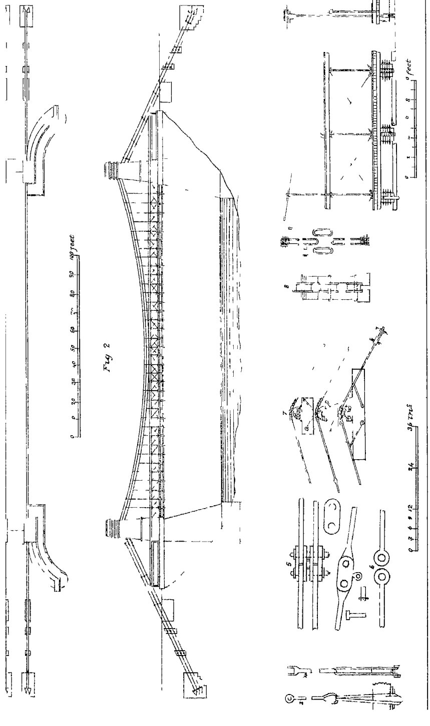
The foundation was laid in April 1828, and the roadway opened to the public in June 1830

The iron of which it is composed is entirely the produce of the Ságar district When the bridge was projected, it was still in the state of ore in the mines, whence it was extracted, smelted, and made into irregular small lumps, in the common native fashion The working of these crude

* As an illustration of this remark, we refer to the description of the rollers on which the chains rest

SUSPENSION BRIDGE AT SAUGOR

Over the Biosi River



impure masses into good bars of the requisite dimensions was a matter of very great labor and difficulty

The bridge is 200 feet in span between the points of suspension

The piers, resting on the solid rock, 6 feet under the low level of the river, are 42 feet high to the roadway, being elevated two feet above the ordinary surface of the country, they have a base of 32 feet by $22\frac{1}{2}$, decreasing upwards in front 1 in 5, and on the sides 1 in 8 feet, which gives on the road a superficies of 21 by 14 feet for each pier On the sides are wing walls or abutments, running back into the bank 26 feet

The pillars, or rather arches, of suspension, have a base of 21 by 12 feet, admitting a roadway of 9 feet broad The arches are 15 feet high, and are faced with accurately wrought stone The points of suspension are elevated 22 feet $4\frac{1}{2}$ inches from the road, the pillars have a total height of 33 feet, and the whole masonry from the rock, 68 feet The piers and abutments contain 82,488 cubic feet of masonry, the arched standards and bridge parapets, 8,900, in all 91,388 cubic feet

The platform measures 200 feet in length by 12 feet broad, and is calculated to weigh, with the chains, $52\frac{3}{4}$ tons Supposing the bridge crowded with men, at 69 lbs per superficial foot, all over the platform, the whole weight would be 120 tons, whence it is calculated that the tension to be sustained at each point of suspension would be 85 632 tons

The suspending chains are 12 in number, arranged in pairs, three pairs on either side, 2 feet above one another They pass over rollers one foot in diameter, and are securely moored in masonry 16 feet below the surface of the road The back chains are 101 feet long, rising at an angle of 27 degrees The angle of the catenarian at the roller is 16° with the horizon, the versed sine at the centre of the curve is 14 feet 3 inches

The 12 main chains are of round bar iron, $1\frac{1}{2}$-inch diameter, bolted together in pairs They are from 15 to 15 5 feet long, and so arranged that the vertical rods may fall from the joints of each chain alternately in parallel lines 5 feet apart The descending chains are square bars measuring $1\frac{1}{3}$-inch on the side, their lower ends pass through 24 conically wrought stones, below which they are capped and keyed (Figs. 1 and 2)

The connecting links of the chains, and indeed all the bolt holes in

the bars, and the drops, are bored out of the solid iron, and broached to fit the bolts accurately (Figs 5 and 6) None were punched at the forge The bolts are $1\frac{1}{2}$-inch in diameter, and are secured by rings, or washers and keys Two adjusting links with iron wedges are fitted to each chain, close to the masonry landward, to regulate its curve and dip Figs 7 and 9)

The method of constructing the rollers is thus described in the memoir —

"The iron rollers 12 in number weigh about one cwt each They are not solid but are composed each about 28 separate pieces of wrought-iron, viz, a centre tube or box for the axle over which thick rings are driven, and an exterior drum between which and the inner ringed tube, flattened bars, as spokes, are driven The centres were broached out clean and true, and cylindrical axles 3 1 inch in diameter were turned to fit, the ends of these axles rest on broad thick iron bearings, mounted on very strong and solid frames of timber well bolted, clamped, and blocked together, covered with pitch cement, and secured in the masonry of the pillars" (Figs 7, 8)

The platform was made in a different mode from those of our Calcutta bridges, as will be understood by the following explanation —

"From the short links set between the centre plates of the shackles, (of the main chains) are suspended alternately from each tier, 74 vertical round rods 1 inch in diameter, connected to a short link (Fig 6) by a 1-inch round bolt passing through it and the socket at the upper end of the bar, at their lower ends the rods have eyes, through which doubled loops of iron pass (Figs 3, 4,) for sustaining the flat bars or girders set on their edges and proceeding from one end to the other on both sides of the bridge

"The flat bars, four inches broad by $\frac{3}{4}$-inch thick, and in lengths of 15 feet, are joined together at their ends by nicely turned bolts passing through bored holes 2 inches in diameter, they are adjusted in their height by double wedges, resting on holders that connect the sides of the loops together The girders are also adjustable in their lengths, the bars that enter the masonry have their ends made broader than the rest of the bars, in which are long openings 2 inches broad to receive wedges (Figs 10 and 11)

"Eight timbers in an upright position are set in the masonry of the pillars, having upright grooves or spaces cut through them, and faced with thick plates of iron, through two of these beams each end bar passes, and may be wedged on either side of the timber towards the land as occasion may require, thus is the whole length of girder drawn more or less to either end of the bridge, and also rendered exceedingly tight and steady The grooves in the timbers towards the river, being about four inches longer than the breadth of the bars, permit them to adapt themselves to their proper directions when drawn lengthwise by the wedges acting against the landward beams, by these means the bars have sufficient play to adapt themselves to the motion of the platform, and all jerks at the pillars are obviated

"Thirty-seven double joists 12 feet long are (having their ends notched below for the purpose) laid on the girders, their centres 5 feet apart correspond exactly with the vertical rods that pass through them, the joists are composed each of two cheeks a foot in depth and 3 inches thick, separated at intervals by four blocks of wood of the same height and thickness, all firmly put together with bolts, screws, and nuts two cleats are nailed to each end of the joists on their under sides, whose ends fit flat against the girder and keep all steady

"Planks 16 feet in length running longitudinally, each plank stretching over three spaces, and regularly disposed as to their joints, are spiked down on the joists, in a direction across these and upon them other planks are spiked down, their lengths being the same as the breadth of the platform The planks are all imbedded in a composition of resin boiled in linseed oil, which in laying on is mixed with ashes The lower planks are 3 and the upper ones $2\frac{1}{2}$ inches thick, they are only 6 inches broad to prevent warping, and have two strong square headed spikes passing through them near their edges, at every crossing of the upper over the lower planks, their points are clinched below the platform, to accomplish which 16,870 spikes, weighing a ton and a half, were used, thus the platform has been rendered extremely strong and firm

"The better to secure the sides of the platform and the ends of the timbers from the weather, a cornice or moulding of wood is nailed along the outside

"The hand-rail is trussed, and consists of iron pillars or stanchions, diagonal braces of iron, and a stout wooden rail running from end to end of the platform, the whole put together with screws and nuts, and adjusting screws for setting up or tightening the diagonal braces whenever required (*Fig* 10)

"The rise in the platform is (as before stated) 9 inches, but the curve of the hand-rail is only 3 inches, to effect which the stanchions that support the rail are of varying lengths The rail being 4 feet 6 inches above the platform at its connection with the masonry, but only 4 feet in the centre of the bridge"

The following are the weights of the chains, rods, and materials of the platform —

	Iron Tons	*Wood Tons*	*Tons*
6 double main chains, joints and bolts,	8 5		
74 vertical rods, with joints, bolts, &c,	1 985		
Flat bars and bolts,	1 726		
37 double joists, blocks, cleats, &c,		6 190	
Bolts, nuts, screws, stanchion plates, flat rings, &c, from beams,	0 383		
Planking 1,124, cubic feet, sál wood,		27 000	
Iron spikes, 16,870, for planking,	1 467		
Iron railing trussed, screws, nuts, &c,	1 314		
Wood for the hand-rail, 52 cubic feet,		1 479	
376 feet of cornice to the platform,		1 531	
	14 775	36 200	50 975
Composition of resin and oil,			1 745
Total weight hung between the pillars,			52 720

THE FINANCE OF ENGINEERING.

By the Finance of Engineering is simply meant that branch of the science which relates to the *Cost and Returns* of Public Works If not so interesting as the strictly professional view of the subject it is quite as important, though unfortunately Engineers are apt to look upon it as something beneath their notice, or at least quite apart from their proper avocations Hence have arisen insufficient estimates—ill-considered schemes—unremunerative works—Railways paying two per cent—and Engineering triumphs like the Thames Tunnel or "the Great Eastern"

It is, indeed, curious how little attention has been paid to this subject Lardner's book on Railway Economy was the first scientific investigation of the question of Transit financially considered, and Sir A Cotton's pamphlet on Indian Public Works, though put forth to advocate the writer's own special ideas, was the first systematic attempt to show the true bearing of Public Works on the general prosperity of the State, and startled the public like the announcement of some new discovery in Science

It may, therefore, be worth our while to bestow a little attention on the subject, if only to show what data we have and what are wanting for a proper enquiry into the laws of Engineering Finance, at least as far as India is concerned

Like any other question of Finance, the subject resolves itself into the two branches of Expenditure and Receipts. By a proper system of accounts we can apportion and classify the expenditure, but of the receipts in return for, or as a direct consequence of, that expenditure, our data are of the very vaguest Yet it is only from a just idea of the proportion between the two that the higher problems of the question can be solved, such as, what portion of its

Revenue a Government is justified in expending on Public Works, or whether it may fairly raise Capital to construct them

As regards the question of Expenditure, the present system in use in India, comprises—1st, The preparation of an Annual Budget, in which the sums to be expended by the several Local Governments, under various classified headings, are annually allotted after a due consideration of actual and probable requirements, and of the total amount that can be spared to meet them Works are classed under the three great headings of Military, Civil Administration, and Public Improvement—the first two comprehending works required for Government purposes, such as Military and Civil Buildings, &c, the last those for the good of the community, such as Municipal Buildings, Roads, Canals, and the like

2nd A system of Accounts by which the actual work done, and its cost are shown, the results being summed up in the Annual Progress Report, which is a corollary to the Budget, and shows the performance of the year as compared with the promise Much difficulty has been practically experienced, and many changes made from time to time in perfecting a system of accounts, which should be satisfactory to Government without being burdensome to the Engineer That a man may be a very good Engineer, and yet a very bad Accountant, is quite certain Yet it is impossible to divest the man who spends money, from being answerable for the way in which it has been spent But that responsibility may yet exist, without compelling the disburser to give an account of it himself, which for a long time was done, until an Engineer found that while one-fourth of his time went in doing work, the remaining three-fourths were occupied in writing about it No system can relieve an Engineer of being answerable for the cheapness or dearness of his work, but by giving him an Accountant, who will be responsible, not to him, but to Government, for the details of expenditure, as *he* will be for the return for that expenditure, the Engineer will be relieved of the most irksome part of his duty, without being freed from his proper responsibility This system is, I believe now being introduced, and will no doubt work well

One much discussed question may just be noticed before quitting this branch of the subject—the question of Establishments, as bear-

ing on the total cost of a work That then amount should bear some proportion to the work done, appears almost an axiom, yet it is not certain that it is even true As a forcible way of putting the case, it has been asked whether (for instance) it is right that it should cost *eight* annas to spend a rupee? But there is another way of putting it, whether if it only cost *four* annas you would not spend *two* rupees? The late Secretary to Government, in dealing with this question, rightly acknowledged the difficulty of drawing the line between the two items of Establishment and Labor, and it is indeed difficult to understand how the two can fairly be separated, or why Establishment is not considered an integral portion of the total cost of a work It is true that to set down the cost of any Establishment as out of proportion to the expenditure incurred, *may* induce a reduction of establishment, but it may also produce an increase of expenditure as an equally effectual mode of diminishing the proportion, and looking at the ultimate aspect of the question, the result to be arrived at is the *total* cost of a work, and not the cost of its several items, whether labor, materials, or establishment The effect of the employment of an efficient, and therefore, an expensive establishment, is, or ought to be, a reduction of other expenditure, and provided there is a reduction on the sum total, the details of that sum ought to be a matter of comparative indifference

Having said thus much on the question of Expenditure, let us turn to the other side of the account and enquire into the Receipts

Public Works may *pay* in two ways—1*st*, They may pay the promoters in the shape of a *direct* return, such as in the case of Tolls on a Road, Water-rent from a Canal, or Traffic receipts on a Railway

Of the above, as regards India, Government has made the Roads, and, anxious to remove all hindrances to free traffic, has given up all Tolls, trusting to receive back its money indirectly, in the shape of customs' dues or otherwise through the general prosperity of the community. Where Roads are made by private individuals, which may yet come to pass in India, the principle on which tolls should be levied is sufficiently obvious without further explanation

Railways are yet in their infancy, and Government has but a

part-ownership in them From the latest returns available, it appears that the traffic receipts on all open Indian lines, of more than 100 miles in length, average in round numbers 10,000 rupees per annum per mile of opened line. If we estimate the working expenses at 50* per cent of the gross receipts, we shall not be far wrong, and the average estimated cost may be taken at 1,35,000 rupees per mile, showing a clear return of less than 4 per cent per annum on the capital expended This is not very encouraging in a financial point of view, but it must be remembered that the traffic is still only partially developed, and that until the great lines are opened throughout, no fair average of results can be struck After that time, and especially as roads and branch railways are made to feed the main lines, a considerable extension of traffic may be looked for, but it is after all by the indirect returns that the value of railways to India must for a long time be judged

As to the direct returns from Canals and other works of Irrigation, it appears that on the only large canals in Upper India, where irrigation has as yet been fully developed (the E and W Jumna Canals), the net annual profit is rather more than 10 per cent on the total cost But it is not probable that this per centage of profit will be realized by the *new* Canals for many years to come The strict financial reckoning now exacted by Government, in which the interest of the capital is reckoned from the commencement of a work, shows that in the case of the Eastern Jumna Canal, that work has already defrayed the whole cost of its maintenance and repairs, *plus* 5 per cent. interest on the capital, leaving a balance in hand at credit of Government Major Brownlow, the late Superintendent of this canal, has reckoned the cost of its construction at 6 5 Rs per acre of average area irrigated, and the maintenance and establishment at 7 annas per acre Colonel Rundall, R E , gives Madras rates as 8 3 Rs for construction, and 6 6 annas for maintenance per acre

Madras works are, however, believed to be generally more profitable than in this Presidency. In a late minute on Irrigation by H E Sir W Denison, the annual *cost* of the water to Government

* It is over this at present, I believe, but will probably be reduced below this per centage before long

is reckoned at 1 rupee for 4,200 cubic yards, the supply being spread over a period of about three months, while the *value* of this water is reckoned at 1 rupee per 1000 cubic yards. Capitalizing the above cost at 5 per cent, the returns show a profit of more than 20 per cent on the outlay.

2nd, Public Works may pay *indirectly*.

The returns in this case are more difficult to determine, and the data are indeed most imperfect, but it will be useful to show what we have, and what are wanting.

Roads operate indirectly—1st, By diminishing the cost of transport, *2nd*, By setting free a large amount of labor, which may be employed otherwise.

The Post-Master-General, N. W. Provinces, in 1850, calculated that the actual haulage of a ton of goods by the Bullock Train cost Government *one anna* per ton per mile on a metalled, and *three annas* on an unmetalled, road, exclusive of prime cost and wear and tear of animals and vehicles.* I have no returns of traffic on any roads, but if the above calculations be accepted, (and they were made from very fair data), and taking the cost of a metalled and bridged road at an average of 7,500 rupees per mile, the cost of repairing it at 300 rupees annually, and interest of money at 5 per cent, it would appear that on any line on which there is traffic to the amount of 5,400 tons yearly, it would *pay* to construct a metalled road.

As to the increase to the wealth of a district through which a road runs, or the extent to which Government, as the road-constructor, benefits by that wealth, I have no means of ascertaining it, but I believe such data might be collected in certain districts, and would be very valuable.

If the cost of carriage is diminished by a metalled road, it is

* Sir A. Cotton gives the following as the actual cost of various kinds of transit in India, per ton, per mile:—

Sea navigation, - - - - - - -	5 to 8 pie ($\frac{5}{8}d.$ to $1d.$)
River do., - - - - - - -	4 pie, or $\frac{1}{2}d.$
Completed roads, - - - - - - -	1 anna, or $1\frac{1}{2}d.$
Imperfect do., - - - - - - -	2 annas, or $3d.$
Unimproved tracks, - - - - - - -	3 annas, or $4\frac{1}{2}d.$

He also gives the actual traffic on the first 125 miles of the Great Western Road from Madras as 110,000 tons yearly.

needless to point out how much more this is the case in respect to a Railway * In the back settlements of America this fact alone has created railways, not as with us as luxuries, but as the first necessities of the settler and the first step towards civilization Rude as they are, often consisting of flat iron bars spiked down to rough logs of timber, laid without ballast on the natural surface of the ground, they answer their purpose and pay indirectly by giving the makers facilities of transport for their produce, and by enhancing the value of their land

Though the same facilities of construction (in the abundance of timber) do not exist in India, yet we have a counterbalancing advantage in the comparative cheapness and abundance of labor, and at least as strong inducements to open up communication between remote districts We have indeed a further inducement, which it is astonishing we have until lately been so slow to recognize—I mean the facility of transport for Troops, Artillery and Stores, which, to a Government in our position, is an absolutely incalculable advantage The strongest Military Government that the world has ever seen, (the Roman,) were not slow to perceive the importance of this —their first step on the acquisition of a new country being to drive a broad Military Road into the heart of it from the nearest Cantonment, made by the soldiers themselves

And this leads me to remark (though it has often been the subject of remark before), on the feasibility of employing a considerable portion of our Army, English and Native, in the construction of Public Works, pressing it, as I would, as an important step in Financial Economy, towards remedying the two greatest acknowledged drawbacks to improvement in India — the (necessarily) excessive Military expenditure, and the want of means of internal communication, for, as the increase of roads would lessen the cost of Military transport, so the employment of soldiers would increase the roads In round numbers we have 70,000 English and 130,000 Native soldiers in India, whereof I would urge that one-half might be employed for 6 months out of the 12, in other than

* Dr Lardner gives the actual cost of transit of goods per ton per mile on English Railway at 1 11*d* The rates charged on Indian lines vary from 7 pie (⅞*d*) to 5 annas (7½*d.*) What the actual cost is I do not know

Regimental work, not only without any sacrifice of efficiency, but with a positive increase to it,* as few can doubt that the men who were well and constantly employed all the year round, off as well as on parade, who could use the spade and pickaxe, the saw and hammer, would be the best men for the real hard work of a campaign. I am fully aware of the difficulties in the way, of the requirements of parade and rifle drill, &c., but making every allowance for that, I think that the proportion above estimated (only *one-fourth* the strength of the Army annually), might be employed as suggested. Now, the money value of this unemployed labor, cannot at the lowest estimate be put down at less than 25 lakhs of rupees, or a quarter of a million sterling, whereof one-half should go into the pockets of the soldiers as working pay, and the rest should be clear profit to Government. This half sum represents 170 miles of first class road annually.

Closely allied to this subject, are the indirect returns which may be said to arise from good Barracks, and such like expenditure which is commonly set down as unremunerative. For the value† of this we must go to Sanitary statistics, but, as I have hinted above, the question is so mixed up with other things affecting the health of the soldier, that it is impossible to say how much saving of life (*i. e.*, of money) is due to good barracks in lieu of bad ones. There are some of our older stations, however, whose statistics, if available, would doubtless throw some light on this head, and allow us to estimate to a very fair approximation, the capital which might be employed in providing good dwellings, whose interest would be the improvement of health in the dwellers. As a practical question, however, it may be said to be unnecessary now, Government being fully

* The great cause of sickness and mortality in the Anglo Indian Army is—*not* drunkenness (that is an effect only of other causes)—*not* bad barracks or unsuitable food—*not* exposure to the sun (for the classes of men most exposed to the sun in India are generally the healthiest)—but *want of occupation*. I am aware of the claims of Regimental Workshops on much of this unoccupied time, and if they could be put on a proper footing, would be the first to advocate them. If the whole of the accoutrements, barrack furniture and fittings, &c., could be made by the men, sharing the profits with Government, no one can doubt the advantage to both. But I hold that any system of *amateur* workshops is simple illusory—it is *playing* at work. It is well known that the French Army in Algeria is largely employed as above suggested.

† The cost of housing the European troops in the Punjab Cantonments was certainly not less than 800 Rs. per man.

y, as well as economy, of not sparing money in this
s been shown in all the Cantonments lately built
lirect returns of Works of Irrigation, we have some
will serve to show their immense value and import-
direct returns, which can be measured or estimated,
creased land revenue obtainable by Government from
nefited, either by waste land being brought under
y the difference in value between *wet* and *dry* culti-
technically termed

arison of data on five first class canals in Upper
d, in hand, or estimated, it appears that the average
cubic foot of water per second of discharge at the
pees, that the average annual value of a cubic foot
crease to land revenue), is 750 rupees, and the
xpenditure per cubic foot is 120 rupees So that
Government is 630 rupees, or nearly 16 per cent,
pital invested, besides the general benefit to the

Madras Canals are more favorable than this,
ol Baird Smith, in one district, at 20, and in
., annually, on the capital invested, and by Sir
at very much more than this

ndirect returns which cannot be reduced to
in remission of revenue, which are often
ng years of drought, in districts where
on,† besides, as before remarked, the
nunity, a prosperity in which Govern-
by the increased consumption of tax-

only made a passing allusion to the
ion of Public Works by Govern-
nt a question to be disposed of in an

n the case of rice at 9 Rs per acre, computed
ol Baird Smith estimated it on the Western
r land revenue only, making a total profit

Ganges Canal alone during 1861 62, was
er rent paid to Government was £70,000

off-hand manner, yet people often think that as soon as they have proved Public Works to be remunerative, it follows, as a matter of course, that it is the duty of Government to construct them, and that if it has not got the money, it ought to borrow it for the express purpose Without entering too far into such a large question, it may be sufficient here to remark—1st, That though it may be the right or interest of the Government to undertake such works, it does not follow it is part of its duty, and that Government has already enough of its own proper functions to perform, 2nd, That it is a pretty generally admitted maxim, that the construction of Public Works is much better left to private enterprise, and that even in the exceptional case of India, the *onus* of proof at least lies with those who would contend for a different principle, 3rd, In answer to those who ask for Public Work Loans on the ground that it is unfair to tax the present generation alone for benefits equally shared by a future one, it may be answered that it is at least as unfair to plunge a future generation into debt on account of speculations, in which they cannot possibly have a voice Government has in effect been compelled to try the experiment and the result of it, in the Railway Guarantee system, is not encouraging, nor is it likely to be repeated With the progress of education the people's eyes will be opened to working together for their own benefit, the influx of capital into the country within the last seven years has been enormous, and it is be hoped we may soon see Railways, Roads, and Canals constructed under the auspices of intelligent and respectable bodies of native proprietors

Here for the present we must stop I am quite aware of the imperfect manner in which such an important subject has been treated, but shall be content if these few remarks may induce others to collect data and compare results, which may be useful in elucidating the laws on which the Finance of Indian Engineering should be based

J G. M

No XXXI

PUNJAB EXHIBITION BUILDING

Designed and erected under the Superintendence of EDWIN E BAINES, ESQ, *District Engineer, Punjab Railway.*

COMMENCED 5th June, 1863, handed over to the Committee 7th December, 1863, opened the 20th January, 1864, by His Honor the Lieutenant Governor, cost, Rs 60,000

The above speedy result of completion was principally owing to the energy of Captain Hall, the Deputy Commissioner (Officiating) in procuring workmen from Lahore and the adjacent towns of Umritsur, Ferozepore, Jullundur, &c, &c, and the liberality of the Punjab Railway Company, in allowing a portion of an organised establishment to be brought immediately to bear on the preparation of the carpenters' and joiners' work

Average number of men employed, 1000 per diem

The style chosen by the Engineer, was that of Belgian Gothic, on account of its grouping in a picturesque manner with the surrounding buildings, and being a style that would allow of freedom of treatment

The building was executed in Lahore bricks, arches, string courses, plinths, &c, in English sized bricks

Roof tiled, with tiles 1 foot square and $\frac{3}{4}$-inch thick, layed on $\frac{3}{4}$-inch boarding, with tarred cloth between that and the tiles Valleys, gutters, &c, lined with zinc

Flooring, boarded with $1\frac{1}{4}$-inch planks, with spaces of $\frac{3}{16}$th-inch between, to get rid of the dust

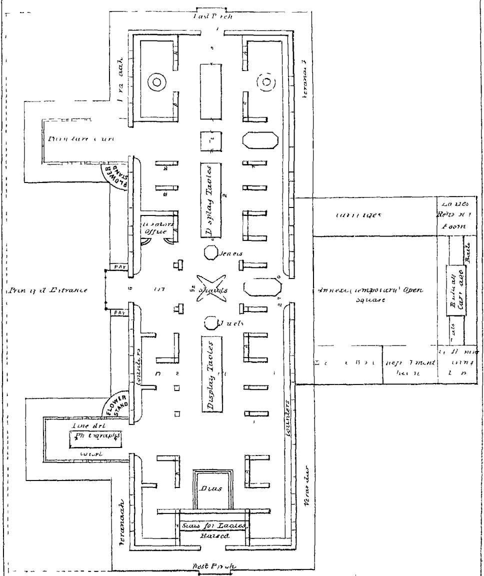
Tables covered with green cloth Dais and Ladies' seats with red velvet, and former with gold fringe dressings

E B

PUNJAB EXHIBITION BUILDING

GROUND PLAN

Scale 10 ft = 1 inch



A A A Glass cases between Arches
B B B Tables

LITH T C PRESS

windows naturally soon followed Grey or red bands were introduced at the Cathedral of Pisa in 1163, and were copied at Sienna in 1243 The rose window is a genuine Germano-Lombard and Romanesque feature, first seen about the middle of the eleventh century The campanile is of Cisalpine origin, and the rich arcade, with its slender colonnettes is a general characteristic of the Lombard style

I have thought fit to draw attention to these facts in the history of the Italian Gothic styles, to show that I have a precedent for each of the main features of my design, and whilst I have amalgamated in my own way the characters of the round and pointed styles, I lay claim to have attempted to do only what the Italians, after a lapse of several centuries, themselves seemed anxious to accomplish

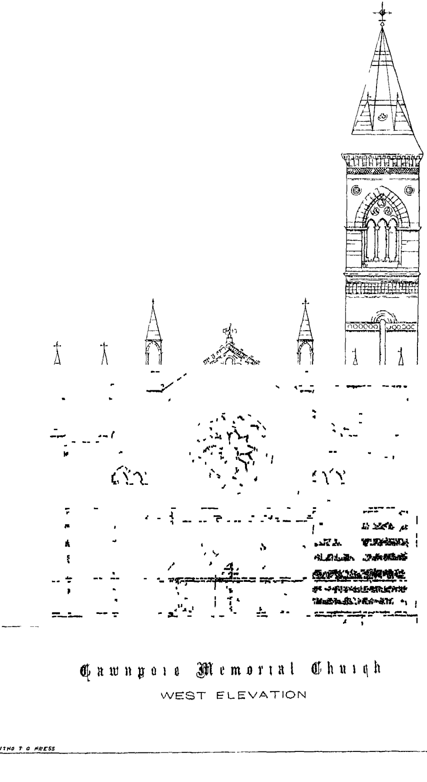
It must, however, be admitted, that they were seldom very successful in grafting the true principles of Gothic pointed Ecclesiastical Architecture on the round-arched styles, probably because they never thoroughly understood them, or, may be, they did not sufficiently appreciate the Architecture of the more Northern Nations If I have been at all successful, it is because those principles are now more widely diffused than they ever were in Italy, and they are better understood

It is proposed to build the walls of the Church of red pressed bricks, faced in part *outside* with Chunar stone in dark grey bands, *inside*, the walls are to be faced solely with stone The roof is groined in stone in the simplest manner The cornices, arches, and columns are to be also of Chunar stone The flooring is also of stone, with a pattern of grey Chinese marble It is not intended to have any plastering either externally or internally, as, after the lapse of a few years, it requires to be constantly repaired, and the tendency of plaster Architecture is constantly to extravagance in detail and bad taste Moreover, it is urged that this Church especially should be a Memorial Church, *ære perennius*, and as such, typical of our enduring supremacy

The dimensions of the Church are as follows —

	Feet	Inches
Extreme length inside,	141	0
Extreme width inside,	50	6
Height of Church,	46	0
Width of Nave,	25	6
Depth of Chancel,	42	0

The Church is capable of affording sittings for 500 persons on the



Cawnpore Memorial Church

WEST ELEVATION

LITHO T O PRESS

ground floor In the gallery at the west end, over the vestibule 100 more persons can be seated The organ is placed in the gallery of the south transept, and there is a corresponding gallery in the north transept, these will seat if required, 100 more persons—thus giving accommodation in all for 700 persons

The method by which the Church is lighted and ventilated and secured against the intensity of glare, forms one of the chief objects of the design In this bright climate light should be admitted with caution, and there is this advantage that it produces a shadowy effect or "dim religious light," which is highly favorable to Architectural grandeur The principal light is obtained from a considerable elevation immediately above the lower passages or aisles It is admitted, *firstly*, through a series of small pointed arches pierced in the outer walls of an upper arcade built over the passages below, *secondly*, through a series of similar arches left in the inner walls of the Church This double arrangement for admitting light will tone down the rays of the sun and obviate any inconvenient glare, while it effectually prevents the rays from falling directly on the people occupying the seats on the floor of the Church By leaving all these openings free from glass, a free current of air is afforded for the ventilation of the Church, whilst in the extreme hot weather, when the Church should be closely shut up, kuskus tatties can be fixed with advantage against the outer openings, and kept constantly wetted by coolies during the service, without at all interfering with the congregation The necessity of using large hanging punkahs, so unsightly in Churches, will thus probably be obviated The rain which beats through the outer arches only, will fall on the floor of the arcade, and be carried away through the down pipes Small openings to act as ventilators have been placed in the passages of the ground floor, and light is also admitted through the deeply recessed windows at the east and west ends, and in the transepts

The Lombard style of Architecture is peculiarly adapted to the above arrangements for admitting light and affording ventilation in the most efficacious and natural way that can be devised for a climate like India, on account of the continuous arcade being one of the most pleasing characteristics of the style Mr James Fergusson, in his *Illustrated Handbook of Architecture*, when speaking of these Lombard arcades, remarks, "There is nothing in the style of which we are now speaking either so common or so beautiful as these galleries These arcades have all the

shadow which a cornice gives without its inconvenient projection, and the little shafts with the elegant capitals and light archivolts have a sparkle and brilliancy which no cornice ever possessed. Indeed, so beautiful are they, that we are not surprised to find them so universally adopted, and their discontinuance when the pointed style was introduced was one of the greatest losses sustained by architectural art in those days."

One word in conclusion before giving the estimates as to the suitability of the design. It has been already stated that the method of lighting and ventilation is peculiarly adapted for a hot climate—so far the design differs from any known Church, but whilst I have departed from the usual plan of Northern Churches in this particular, on account of the climate, I have adhered to the orthodox plan of a Church appointed for celebrating the rites and ceremonies of the United Church of England and Ireland. I have moreover endeavored to give to the exterior and interior at least an Oriental stamp, by the introduction of colored bands, which, so far as I remember, had their origin in the East amongst the Tartar tribes, and were introduced by them into every country they occupied.

Estimate

The prices have been based on the rates of work prevailing at Cawnpore, which were furnished to me by the Executive Engineer of the Cawnpore Division of Public Works, by direction of the Secretary to Government, N. W. Provinces, P. W. Department.

Full allowance has been made in addition to those rates where there was more than ordinary labor attached to the work, and 10 per cent. has been added to the Estimate to cover unforeseen contingencies.

c. f.		R.	A.	P.
6,500	Rough dry ballast, at Rs. 6 per 100,	390	0	0
24,225	Brick work in foundations, at Rs. 18 per 100,	4,360	8	0
97,250	Ditto above, including extra labor in connection with stone facing, &c., at Rs. 20 per 100,	19,450	0	0
750	Ditto, moulded in small arches of outside cornice, at Rs. 30 per 100,	225	0	0
19,850	Chunar ashlar stone in plain faces, 6" thick, including beds and joints, at Rs. 1-8 per foot,	59,775	0	0
6,220	Ditto in arches, at Rs. 2 per foot,	12,440	0	0
1,329	Ditto in plain moulding, at Rs. 2-4 per foot,	2,990	4	0
	Carried forward,	98,630	12	0

ESTIMATE.—(*Continued.*)

		R	A	P
	Brought forward,	98,630	12	0
389	Chunar ashlar stone in moulded plinth, at Rs. 2-8 per foot,	972	8	0
1,748	Ditto in columns, at Rs. 3 per foot,	5,244	0	0
675	Ditto in moulded bases, at Rs. 3-4 per foot,	2,193	12	0
1,250	Ditto in large and small carved caps, at Rs. 4-8 per foot,	5,625	0	0
460	Ditto in moulded blocks, at Rs. 2-4 per foot,	1,035	0	0
s. f.				
1,320	Khoa floor, at Rs. 18 per 100,	237	9	7
3,800	2½ inch Chunar stone paving, at Rs. 28 per 100,	1,064	0	0
2,000	1-inch China marble ditto, at Rs. 50 per 100,	1,000	0	0
1,475	1-inch Tile gutter, at Rs. 15 per 100,	221	4	0
c. f.				
741	Sál timber in roof, at Rs. 4 per foot,	2,964	0	0
385	2½-inch plain Sissoo-wood doors, complete, at Rs. 1-8 per foot,	577	8	0
45	1½-inch ditto ditto ditto, at Rs. 1-8 per foot,	67	8	0
s. f.				
9,450	Corrugated Iron, at Rs. 45 per 100,	4,252	8	0
c. q.				
15 3	Milled lead, laid in ridge, at Rs. 28 per cwt.,	441	0	0
3 1	Wrought iron, at Rs. 28 per cwt.,	91	0	0
s. f.				
420	16 ounces sheet glass, at Rs. 0-12 per foot,	315	0	0
	Communion Table of Sissoo wood,	50	0	0
	Stone Altar Rail,	150	0	0
	Ditto Reading Desk,	250	0	0
	Ditto Pulpit,	500	0	0
	Ditto Font,	400	0	0
	Seats for 600 persons of Sissoo wood,	3,600	0	0
	Rupees,	1,00,882	5	7
	Low enclosure wall with gateways, gates, and roads of approach,	6,117	10	5
	Total Rupees,	1,07,000	0	0
	Add 10 per cent., for contingencies,	10,700	0	0
	Grand Total Rupees,	1,17,700	0	0

CALCUTTA, }
August, 1861. }

W. GRANVILLE.

[NOTE.—Subsequent experience showed that the estimate was insufficient and it was afterwards raised to Rs. 1,51,131. This sum was sanctioned by Government, and the building is now in progress.—ED.]

No XXXIII

LOCAL ATTRACTION

On the Local Deviation of the Plumb-line from the True Vertical, as affecting the accuracy of a Trigonometrical Survey BY LIEUT HERSCHEL, R E, *First Assistant, G T S*

IT is not easy at this period of our knowledge of the constitution of the earth's crust, to do more than speculate on the importance which this subject may one day attain, but no one who has even a slight acquaintance only with the way in which gravity manifests itself, as "local attraction," will hesitate to acknowledge, that even in our present state of ignorance regarding it, attention will not be drawn to it in vain

It is not intended in this paper to enter into any minute details, so much as to point out in general terms the way in which local attraction manifests itself, and the difficulties which must always be met with in endeavouring to determine its force, and the origin of that force I may perhaps, too, venture to speculate on the probable results of a more intimate knowledge of its general laws, or hazard an opinion on the direction which any attempt to collect data should take, so as best to discover those laws

Before attempting anything of the kind, however, let us understand exactly what is meant by the term "local attraction" Many people who use the word frequently, without having had the good fortune to come across a late article in the "Cornhill Magazine," (to which I shall have occasion to refer again presently), or on whom a different view of the matter has not been forced by some equally startling facts, would say, the words referred to the deflection of the plumb-line, due to the lateral attraction of some mountain mass, and that this is the more natural view is not to be denied,

for mountains are palpable things, and we naturally expect them to attract a plummet more or less, and so deflect it from the perpendicular, and though a moderate exercise of our reason would lead us to argue that variable density of subterranean strata would produce the same effect, still the fact remains that, that variable density is little more than an hypothetical one In short we might reasonably look for deflection in a certain direction near a mountain, but we should hardly do so in a plain *Local* attraction is in common parlance almost synonymous with *Mountain* attraction I prefer, however, in the present instance to be understood to mean "a force, due to local constitution *or* configuration of the materials forming the earth's crust, which causes deflection of a plumb-line from the direction of the normal," *i e*, from the direction which the plumb-line would have but for local inequalities of surface or density (I just now made use of the expression "deflection from the perpendicular" According to ordinary ideas "the perpendicular," is the direction of gravity, *i e*, of the plumb-line when in a state of rest, but no sooner do we come to talk of "local attraction," than we are compelled to distinguish between "the perpendicular," *i e*, the direction of the normal, and the direction of gravity)

Let the reader conceive a plumb line suspended from the ceiling, with the point of the plummet just grazing the surface of a sheet of paper on the table before him, on which are drawn lines defining the four cardinal points, and let him adjust the paper so that the point of the plummet shall coincide with the intersection of the cross lines, and let him conceive this state of things to represent the absence of all local attraction Now let a magnet be laid on the table any where, (the plummet being of iron), the latter will move and take up a position, differing more or less from its former one according to the distance and power of the magnet, &c, and permanent so long as the magnet continues undisturbed This is an exact parallel to the state of things when local attraction exists The only difference is to be found in the nature of the attractive force, which is here magnetic instead of molecular, and in one other very important respect, which constitutes in fact the whole difficulty, and I may add, interest, of the subject, viz, that whereas in this experimental illustration, it would be easy *to measure the amount and direction* of the disturbance directly and absolutely, in the case illustrated we can do neither In other words we should have a more exact parallel, were a clean sheet of paper substituted for

that on which the cross lines were drawn and were we asked to point out the spot where the plummet would rest, were the magnet removed We could not do it *directly and absolutely*, neither can we, or have we, or shall we ever be able to assign the absolute amount and direction of local attraction at any place But we may *guess* any number of times, and our guesses being rightly biassed, we may approximate very closely to the truth. Nay, more than this, though judicious guessing will help us more quickly perhaps to a conclusion, we may arrive at the same conclusion in time without such questionable help

Dispensing for a time with the assistance of the magnet, conceive the plummet deflected by the force of local attraction alone In the absence of any positive knowledge of the amount and direction, or even of the very existence of such deflection, let us assume that there is none, and that a dot on the paper immediately below the point of the plummet represents the position due to no attraction, at that point of the earth's surface where the plumb-line has been suspended Now, let the reader conceive himself, his table, paper and plumb-line, transported to a place, say twenty miles off, and let him, for the present, take it for granted that it would be possible so to deposit him and his apparatus, that the dot he made at the first station should be in the exact position which the plummet would indicate were the local attraction at the two stations identical, (*i e*, on the assumption that there was none at the first, were there none at the second also), and that his paper should maintain the same position with regard to the north and south points Being so deposited, he observes that the plummet indicates a different point altogether, and he is driven to the conclusion that there *is* local attraction at the second station and that its amount and direction are measurable Having marked this new point he is transported to a third, and so on, at each new station making a dot to indicate the position which the plummet occupied When a large number of stations have been thus visited, the paper will present a group of dots, more or less evenly scattered or clustered, according to the nature of the local attraction in the several districts visited * Now since each individual dot occupies a position relatively to No 1, it follows that each occupies a positon relatively to any one of them, or to any arbitrarily assigned imaginary point among them Let the centre of gravity of the whole be

* The reader is cautioned against confounding this experimental chart of points indicated by the plummet, with a chart of the corresponding stations There is no connection between them as far as appearance is concerned

such an imaginary point, then it is clear that this is the point which the plummet would have indicated at some station where the local attraction partook equally of the character of the attraction at all the stations visited, quite independently of our original assumption of absence of attraction at No 1 That assumption would be justified or not, according to the proximity of dot No 1, to the centre of gravity, but whether true or not matters little now, for we have obtained *a mean direction of the plumb line*, and by reference to it, can assign a numerical value of the absolute deflection at any one of the stations visited, (No 1 included) When I use the word *absolute* in this place, however, I am assuming that the *mean* direction is the *true* one, which I am perhaps hardly justified in doing without some caution Means never do more than approximate to the truth, and that only in the absence of any bias, constant for the whole or great part of the quantities whose mean is taken Thus, for instance, were the above experiments confined to a portion of the surface of the earth in the vicinity of a lofty mountain range, we might fairly say that the *mean* direction of the plumb line would very erroneously represent the *true* direction of the normal To ensure the absence of any such bias, the stations visited must be very numerous and scattered over the entire globe, either at random, or according to some law quite independent of the configuration of the earth's surface We might indeed confine the observations to a small portion of the globe, as England for instance, or the Indian peninsula, but it would be on the distinct understanding that the result would be erroneous by a quantity, small perhaps, but on no account to be ignored, which would have to be called "mean English (or Indian) deflection, amount unknown," and this is all that we can at present hope to do, even if we can do so much

The reader will remember that he was called upon to take for granted, that, it was possible so to deposit him and his table and paper at two places that, were there no local attraction at either (or the same at both), the point of his plummet should indicate the same spot on his paper at both, so that his paper should hold the same position with regard to the north and south points The object in view in so placing the paper was to show at a glance the amount and direction of the deflection at the second station, relatively to that at the first It is unnecessary to go into detail to show how this could be done It will be sufficient to show that the results thus intended to be illustrated, can be obtained To do this I must first re-

mark that the position of a point on a spheroid of revolution of known excentricity, is known, as soon as its latitude and longitude (measured from some assumed fixed point) are known. Now the latitude of a point is defined as the angle which the normal makes with the plane of the equator, a quantity clearly indeterminate except on the assumption that the direction of the normal itself is known. This definition must therefore be modified, and we must acknowledge two latitudes, a *local* or apparent and a *true* or astronomic latitude, of every place. The difference is the resolved portion of the deflection, in a north and south direction, arising from local attraction. *Assuming absence of attraction at A*, we can determine its position on the spheroid, and thence by geodetic triangulation lay down the position, and determine the *quasi* astronomic latitude of B. We can also, by direct observation, determine the *local* latitude of B, and comparing the two, we have the resolved portion of the deflection at B, in the direction of the meridian. Again by direct observation at A, and the help of the intermediate triangulation, we can lay down the *quasi* astronomic meridian at B, comparison of which with the result of direct observation at B, determines the resolved portion of the deflection at B, in the direction of the prime vertical.* Combining these two, the reader will allow that we may obtain the amount and direction of deflection at B, always on the assumption of *no attraction at A*, the truth of which assumption, as I said before, is after all immaterial.

It will have been noticed that the possibility or impossibility of doing as above, depends on our power of triangulating between all the points visited. It is, therefore, evident that we are to all intents and purposes restricted to comparatively small and isolated portions of the earth's surface. Thus we might, were there no other difficulties in our way, obtain a mean direction of the plumb-line for England, for France, for Prussia, for Russia, nay, as things now stand, perhaps for the greater part of Europe as one portion, for North America as another, for India as a third, and so

* Some explanation is perhaps needed of the reason why deflection in a direction perpendicular to the meridian is measured by determining the angular deviation of the local from the true meridian, rather than *the actual difference between local, and true longitude*. The fact is that at present we have no means of determining local longitude with any degree of accuracy at all comparable with that to which we can attain in latitude. But inasmuch as longitude is merely another word for "position of meridian," we come to the same result by ascertaining the latter. This we do by measuring the horizontal deviation of the point, where a local (*i. e.*, deflected) vertical circle passing through the pole meets the horizon from the point where a true vertical circle would meet it. This angular deviation is to the resolved portion of the deflection in a direction perpendicular to the meridian, as the tangent of the latitude is to unity. Hence deflection perpendicular to the meridian (or in longitude) = horizontal deviation of meridian × cotan, latitude.

on for the chief portions of the earth's dry surface, but beyond this we cannot go until these several portions shall have been connected by actual triangulation, a tolerably remote prospect. And even then we shall have covered but a third of the globe with connected points. How the remainder is ever to contribute its due share of data of the required kind is to me a problem so incapable of solution that I think, I was justified in saying that "we never shall be able to assign the absolute amount and direction of local attraction at any place."* It may indeed be said in reply that we never can obtain perfect accuracy in any thing in this world. Granted; we can at any rate aim at local accuracy, and we shall soon see that the attainment of even this, is hardly better than a wild speculation as yet.

To enable us the better to estimate our powers, I will now draw attention to the magnitude of the quantities which we have to measure, and the degree of accuracy attained or attainable in the means of measurement.

At page 661, of the "Account of the Principal Triangulation of the Ordnance Survey of Great Britain and Ireland," there is a table showing the results of direct computation of the deflection at 16 points, independently of any considerations other than those founded on the configuration of the neighbouring surface, and the assumed mean density of the materials forming them. Their range is about $\pm 5''$ in the direction of the meridian. Valuable as these computations are, they show rather what the deflection *should be* according to certain assumed laws than what it is *found to be* according to certain laws which we desire to know more about. I therefore pass on to the more reliable results of actual observation.

In the "Cornhill Magazine" for October, 1862, appeared a notice of the amount of local attraction detected near Moscow, within a circle of 21 miles across, by comparison of actual observation with the results of inter-triangulation. It has a range of $\pm 8''$. Even allowing the existence of large errors of observation, the mere inspection of the data is sufficient

* I have perhaps hardly laid sufficient stress on the necessity of even distribution of the stations of observation over the whole globe, in order to approximate as nearly as possible to the only conditions under which a perfectly true result could be attainable, viz., when *every* point on the earth's surface is one of an infinite number of stations of observation. The attraction of the sea being negative, (*or rather, less than what would exist were the sea land*), *it is clear that the* negative influence of an Eastern sea will produce a constant bias unless counteracted by a corresponding bias caused by a Western sea also. The Indian peninsula presents a case in point, but although Eastern and Western bias may here be fairly assumed as counteracting one another, there still remains a Southern negative influence due to the absence of a counteracting Northern sea. Pursuing this train of thought, we come to the conclusion that so long as we are restricted to land surveys and stations we shall fail of eliminating bias, owing to the known preponderance of sea in the Southern, and land in the Northern hemisphere.

to lead to the conclusion of relative deflection amounting to $\pm 10''$ within a direct distance of 12 miles on an appreciably level country.* It is not easy to restrain speculation in presence of such facts as these.

Here in India we are ready to accept $30''$ to $40''$ of deflection as reasonable, within short distances of the Himalayan range. But we rarely trust anything above $10''$ or $15''$ elsewhere—not that we have any reason to doubt the *possibility* of such large quantities, but simply that such cases as that at Moscow, have not yet been substantiated sufficiently to remove old prejudices.

The accuracy of any measure of local deflection depends—1st, On that of the trigonometrical deduction from origin, and 2nd, On that of direct observation of the local latitude and meridian. The latter is tolerably uniform, $1''$ to $2''$ representing the limit of probable error, beyond which it would appear unwise to attempt any deductions. The former, on the other hand varies greatly, so greatly indeed that nothing but the most careful consideration of all the varying circumstances which enhance or detract from its value, such as instrumental appliances, system of triangulation, of observation, and of reduction, character of country traversed, &c., &c., would justify even a guess at the degree of accuracy to be expected; at the close of any triangulation of given length, *cæteris paribus*, however, it would probably be as the square of its length. Assuming that an error of an inch per mile may fairly be expected in the length of the closing side of a series of triangles of 500 miles in length, (which be it understood is the very least that can as yet be looked for in the best triangulation), and we have at once an error of half that amount for every mile of the whole length, or an error of 20 feet in direct length. But this gives a very inadequate idea of the probable error of position of the end of the triangulation, for not only would error in linear unit and error of observation, producing erroneous *direction*, very considerably increase this uncertainty, but we have an element of uncertainty arising from the very nature of the question we are dealing with, which it would seem impossible to guard wholly against. Let me explain. In illustrating just now the process by which the absolute amount of deflection might be determined (by the help of perfect triangulation over the entire globe) by reference to a mean direction of the plumb-line I assumed *no attraction*

* I speak from recollection of a chart of the district, accompanying a report on the subject, alluded to in the 'Cornhill Magazine.'

at the origin, and afterwards asserted that the result was independent of such an assumption That assertion was only true when the distance from A to B was supposed short It was quite true that, however false the assumption of no attraction *in the direction of the meridian* might be at A, such assumption would in no respect vitiate the result at B relatively to A, whatever the distance, but the case is very different as regards *error of direction of meridian* (*i e*, deflection in a direction *perpendicular* to the meridian) at A The position of B, trigonometrically deduced from A, is entirely dependent on the truth of the assumption in this respect, when the distance is great, and therefore also the deflection obtained by comparing such position with that assigned by direct observation To illustrate more clearly my meaning, and to show the great importance of starting at some place, where we have reason to believe that the assumption of no attraction *perpendicular to the meridian* is a true one, let us suppose the station A to be on the sea coast at Bombay, and B on the sea coast at or near Vizagapatam, on the opposite side of the peninsula, the two stations being connected by perfect triangulation Let the meridian have been determined by direct observation at Bombay There is a strong probability amounting almost to certainty, that the plumb-line is then drawn considerably to the eastward owing to the preponderant attraction of the land, and defective attraction of the sea, and the consequence of such deflection would be that the local meridian would fall to the eastward of the true meridian Let us for the sake of example assume the horizontal deviation so caused to be 10″ With azimuths founded on this local meridian let the triangulation have been computed and plotted It is evident that every point in it, B among others, will have a position assigned to it slightly to the north of its true position The error will be represented in feet by 5280 × sin 10″ × distance from A in miles, or, taking the breadth of the peninsula here at 700 miles, B will be assigned a position 180 feet south of its true position, corresponding to an error in latitude due to deflected azimuth at the origin, of nearly 2″ By exactly this amount would our determination of relative deflection *in the direction of the meridian* at the two points A and B be erroneous from this cause alone This might in practice be considerably increased from the several causes of error before alluded to And be it observed that the deviation here assumed, viz, 10″ is by no means an improbable one

I think this is sufficient to show the importance of seeking a locus of no attraction for observations for initial azimuth.

We have now arrived at the following conclusions:—1st. That the amount and direction of local attraction at any place are unassignable *à priori*.

2nd. That the *relative* amount between two points not very far apart may be determined with tolerable accuracy but that at distances exceeding (say) 200 miles, none but triangulation of the best description can be expected to give reliable results.

3rd. That great accuracy cannot be looked for even over small areas owing to the labor and expense of astronomical observations of the requisite value.

Lastly, that until the whole habitable (and inhabitable) globe, or, to confine ourselves within reasonable limits, until the whole of India, and more especially the Southern portion, shall have been covered with first class triangulation such as the North and West alone can as yet boast of, here and there, and with numerous astronomical stations (whose present number may be counted on the fingers) it is vain to do more than speculate on "Local Attraction."

In one word, we know little on this subject but our own ignorance, the necessity of knowing more, and the difficulties in the way of the attainment of such knowledge. Reliable data we have absolutely none that I care to call such—and with this confession of ignorance I leave the subject for the present.

J. HERSCHEL.

No XXXIV

TURBINE AND CENTRIFUGAL PUMP,

AT ASUFNUGGUR, ON THE GANGES CANAL

Constructed at the Roorkee Workshops

The Centrifugal Pump at Asufnuggur was ordered by Col Turnbull, Superintendent General of Irrigation, N W Provinces, during the famine year 1860-61, as an experiment to test the practical value of irrigating the high land at these Falls, which owing to the great distance from the Puttree Falls (the ones immediately above those at Asufnuggur), and the difficult nature of the ground, rendered the bringing of a rajbuha remuneratively, impossible, this will readily be seen when it is stated that the Puttree Falls are more than 12 miles from Asufnuggur, and the valley of the Solani intervenes between them

The machinery is placed at the side of the lock, in the mill channel, a wooden box or trough conducting the water from the upper mill channel to the supply pipe of the Turbine, and also to the Centrifugal Pump The description of Turbine used, is the ordinary re-action one of Messrs Whitelaw and Stuart, the Centrifugal Pump is also the ordinary one, with four curved vanes The Turbine and Pump are fixed on the same shaft, and make the same number of revolutions per minute

The action of the machine is as follows —When the valve at the bottom of the wooden box is raised, the water descends through the pipe, and issues from the four orifices of the turbine, the re-action of this water issuing causes the turbine to revolve, at the same time the pump draws the

water into the centre of its disc and throws it out at the circumference, from which it rises by the vertical pipe to the channel above The arrows show the direction the water takes

The pump being placed in the water there is no necessity for fanging it, the valve only requires to be raised, when the water immediately commences to flow, and continues to do so night and day, without trouble and with very little attention

Appended is a memo from Lieut Forbes, R E, Superintendent Northern Division, Ganges Canal, giving the quantity of land irrigated, and the revenue derived from it, from this it is evident that the pump has been a success There is a further saving from the pump, which is not shown in Lieut Forbes' statement This is the irrigation of the mangoe garden at the Falls previous to the pump being erected, this garden was irrigated by bullocks at a cost of 18 rupees per month, during the months that irrigation was necessary If the gain on this head had been included, the result of what is only to be considered as an experiment, would have been more favorable

ANGUS CAMPBELL,
Officiating Superintendent Workshops

Memo on the Asufnuggur Pump, by LIEUT FORBES, R E *(referred to above)*

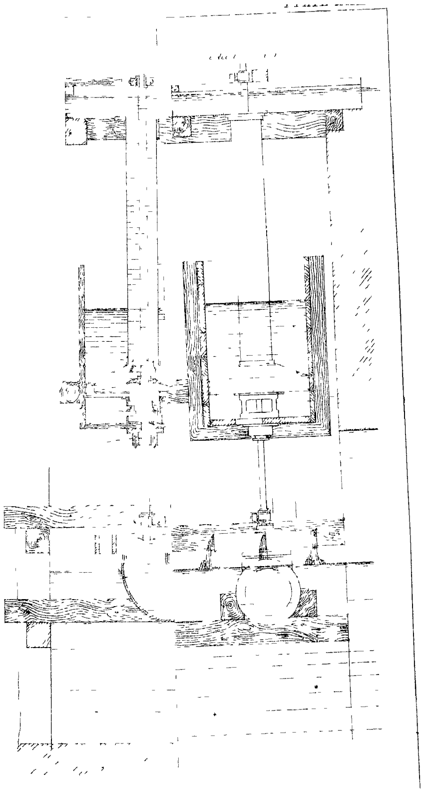
The following table shows area irrigated and revenue derived, from the machine since it was first erected —

	Beegahs	Bis	R	A	P
Rubbee, 1861-62,	44	2	36	1	6
Khureef, 1862,	41	10	59	7	2
Rubbee, 1862-63,	0	0	0	0	0
Khureef, 1863,	21	10	28	2	8
Rubbee, 1863 64,	129	14	107	15	10

This latter amount of 129-14, is I fancy, below the mark I only received the revenue papers a few days ago, and think the true measurements will be somewhere about 200 beegahs

The pump is capable of affording irrigation to about 230 beegahs, and the revenue that could be derived from it should be about Rs 300 per annum, viz (Rubbee, Rs 160, and Khureef, Rs 140) The cost of the pump was Rs 1,176, so the income derived from it should be 25 per cent on the original cost

J G. FORBES



LITHOTO PRESS

No XXXV

NOTES ON RETAINING WALLS

By "DHARWAR"

WATER PRESSURE

PRACTICALLY the maximum pressure against walls is that produced by water, the formula for which is, $P = 31.25h^2$, which multiplied by its leverage $\frac{h}{3}$ is equated with the moment of stability of the wall which is $W_1 h \frac{b^2}{2}$, and therefore

$$\text{Breadth of base} = b = \frac{4.56\,h}{\sqrt{W_1}} \qquad (1)$$

where, P = horizontal pressure of material retained, in foot pounds per unit of length of wall

h = height to top of wall, which is always supposed level with upper surface of mass retained

b = breadth of vertical rectangular wall, at base

W_1 = weight of masonry per unit,

all units being in feet pounds, and the wall to resist being supposed to be a vertical rectangular wall of rubble in mortar, which can only over-set by turning round the outer angle of its base

Where specific gravity of masonry is given, the above formula becomes

$$b = .58\,h\sqrt{\frac{1}{S_1}} \qquad \ldots \quad (1a)$$

S_1 being the specific gravity of the wall

In the above equations, W_1 and S_1 being the only variables, it will be easy to obtain average values for b, and such when obtained I purpose to equate with walls of other sections, which are more valuable in

practice, and to make diagrams of these, so that the relative dimensions of various sectioned walls may be seen at a glance

If we assume stone masonry to vary between 120 and 150 lbs per cubic foot then, b will be equal, as

a Maximum $58\,h\sqrt{\frac{1}{1\cdot9}}$ and as

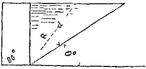
a Minimum $58\,h\sqrt{\frac{1}{2\cdot4}}$, or, 42 and 36 times h, and averaging 39 h, this gives a wall of about 15 feet base for a height of 40 feet, for diagram of which see *Fig* 1, in sheet

For a brick wall $W_1 = 100$ $b = 46\,h$

EARTH PRESSURE

A wall being properly drained at back, will, when it retains earth, have to sustain, as a maximum, the pressure of *loose* earth

I The ordinary case of this is that of a bank whose top is on a level with the top of the wall and is horizontal, the pressure is usually calculated by the formula.



$$P = \frac{W\,h^2}{2}\tan^2 \tfrac{1}{2}\,a \qquad (2)$$

and multiplying by $\frac{h}{3}$ we have its moment which, equated with $\frac{W_1\,h\,b^2}{2}$ (the moment of a vertical rectangular wall), gives

$$b = 58\,h\tan\tfrac{1}{2}\,a\sqrt{\frac{W}{W_1}} \qquad (3)$$

where $a = (90^\circ - \theta)$

θ = angle of repose or natural slope, and its tangent equals the co-efficient of friction of earth

W = weight of loose earth per unit, and the other symbols, as before

In Weale's Engineer and Contractors' Pocket Book, for 1862, is published Mr Neville's deductions on retaining walls, and he has there given a Table, the use of which facilitates the calculation of strength of walls for every case, using his tabular co-efficient = Cf we have for any bank, whether horizontal, or not,

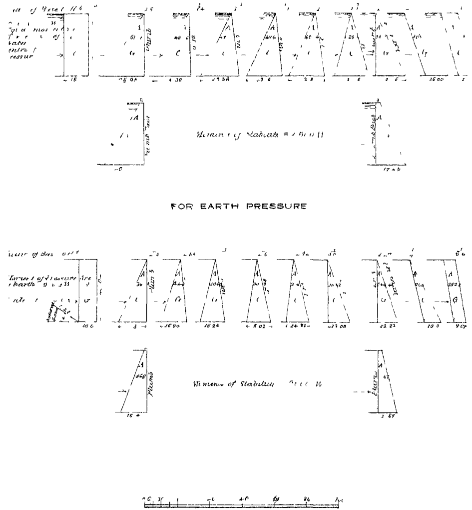
$$P = Cf\,Wh^2 \quad \ldots \quad (2a)$$

and in case, as equation (3) $b = \sqrt{\frac{2\,P}{3\,W_1}} = 82\,h\sqrt{Cf\frac{W}{W_1}}$ .... (3a)

DIAGRAMS OF RETAINING WALLS OF EQUAL STRENGTH

FOR WATER PRESSURE

FOR EARTH PRESSURE



In equations (3), (3*a*), the variables are, for any given height, $\frac{W}{W_1}$, and $\tan \frac{1}{2} \alpha$, or $\left\{ Cf, \frac{W}{W_1} = \frac{S}{S_1} = \begin{matrix} \text{specific gravity of earth} \\ \text{,, of wall} \end{matrix} \right\}$ for earth, S will range from 1 5 to 1 9, and for rubble, S_1 from 1 9 to 2 5

Tan $\frac{1}{2}$ α or its value $\left(\frac{90 - \theta}{2}\right)$ will vary with θ, which ranges from 30° to 46°, and the tan $\frac{1}{2}$ α from 58 to 40

The possible combinations of these variables is infinite from,

$$\text{as a Maximum, } b = 58 \times 58\, h \sqrt{\frac{1\ 9}{1\ 9}} = 33\, h$$

$$\text{to a Minimum, } b = 58 \times 40\, h \sqrt{\frac{1\ 5}{2\ 5}} = {\cdot}18\, h$$ and the mean of these co efficients, or 25 is probably near the truth for all usual cases It is evident by the following tabular arrangement, of several values of the variables with the deduced bases in terms of the height that, excepting the extreme cases, the above average co efficient is suitable for most cases, also it is evident that the variation of the value of the co efficient due to the ratio $\frac{W}{W_1}$, is of more consequence than that of the tan $\frac{1}{2}$ α, hence that the difficulty of determining b, from direct experiment, is not very great if we assume an approximate angle of repose, because $\frac{W}{W_1}$ can be obtained by any person having command of a set of scales and weights

TABLE I

	DATA			CALCULATIONS				
No	∠ of repose	Weight of c f of bank	Weight of c f of wall	$\operatorname{Tan} \frac{90-\theta}{2}$	Square root of ratio of wall to bank	Constant multiplier	Breadth of base	REMARKS
	θ	W	W_1	$\operatorname{Tan} \frac{\alpha}{2}$	$\sqrt{\frac{W}{W_1}}$		b	
1	17°	135	140	74	98	58	42 h	Wet clay, basalt rubble, } Rankine.
2	4[illegible]°	120	130	41	96	58	23 h	Damp clay, limestone do } Rankine.
3	2[illegible]°	90	120	59	87	58	25 h	Mixed sand and earth dry, } Rankine.
4	48°10	97	125	43	88	58	22 h	Dry earth and rubble } Mahan
5	54°	106	143	32	86	58	16 h	Moist do basalt do } Mahan
6	54°	97	106	32	95	58	18 h	An average case with brick or light [stone
7	34	112	130	53	93	58	28 h	Earth Neville
8	43°	55	120	43	67	58	17 h	Moist black soil, slate rubble } Dharwar by self.
9	40	82	120	46	82	58	22 h	Red soil loose do } Dharwar by self.
10	34	100	100	53	1 00	58	31 h	Earth and brick wall
11	37°	94	120	50	88	58	25 h	Average cases
12	37°	94	130	50	85	58	24 h	Do
13	34°	100	110	53	95	58	29 h	Do

Numbers 8 and 9, give the results of some experiments I have made in this country on the values of $\frac{W}{W_1}$ and θ, but I am convinced that each case must be determined by its own experiments, and that unless such be done and the data be well assured, it will never be safe to design a vertical faced rectangular retaining wall, with a base less than $\frac{1}{4}$ the height, even a shower of rain may alter the value of θ and W, or carelessness on the part of an overseer, in neglecting the precautions of back drainage and "weeping holes" at base, may upset the value of the most accurate investigation I have therefore assumed a base of $\frac{1}{4}$ for the wall, for earth pressure, in the diagrams

Law, in Weale's Series on Rudiments of Engineering, framed a table, which I give, adding a column showing the base which I deduce from his constant multiplier (k) equal W $\tan^2 \frac{a}{2}$, in equation (2), or Cf, in equation ($2a$)

In calculating, I assume $W_1 = 140$, which although a high value, is obtained as follows —

$$\left.\begin{array}{l} W_s = \text{weight of stone 150 lbs} \\ W_m = \text{weight of mortar 106 lbs} \end{array}\right\} \text{mixed in the proportion}$$

of $\frac{1}{5}$ mortar to $\frac{4}{5}$ stone, which is a fair proportion for good rubble

$$\text{Hence } W_1 = \tfrac{4}{5}\ W_s + \tfrac{1}{5}\ W_m = \frac{(4 \times 150) + 106}{5} = 140 \text{ lbs}$$

nearly Equation (2) with these values becomes

$b = 82\ h \sqrt{\frac{h}{40}}$ from which equation the last column of Table II is calculated

TABLE II

No	Nature of Bank	Weight in lbs per c f	Angle of repose	Constant multiplier $= k$	Breadth of base in terms of height
1	Fine dry sand,	94° to 119°	30° to 40°	15 66 to 12 938	22 to 246 h
2	Loose dry shingle,	106° to 91°	34° to 13° 10′	12 06 to 8 81	24 to 17 h
3	Common earth (dry),	106	54°	5 595	156 h
4	Do do (moist)	125	55°	6 213	16 h

Having by any of the equations, or tables, got the proportions of a vertical faced rectangular wall, it will always be desirable to know what other walls may be substituted for them, practically, there is a great waste of material in rectangular walls, and, of all wall sections those

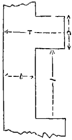
that are, or approximate to, triangles will be the most economical as in those the mass of masonry will be, at every point, proportional to the pressure

To obtain walls of equal strength we may equate their moments with that of our standard wall, which is $W_1 \frac{hb^2}{2}$ for the unit of length, or area of section × leverage, the weight of unit being neglected as common to both, therefore

$$A\,\frac{b}{2} = A'\,y \qquad (4)$$

where A = area of standard wall
A' = area of required wall
y = leverage, round outer angle

II For a counterforted vertical rectangular wall, this equation becomes $\frac{hb'^2}{2} = \left(\frac{hlt'}{2} + \frac{hCT'}{2}\right)\left(\frac{1}{l+C}\right) = \frac{h}{2}\left(\frac{lt^2 + CT'}{l+C}\right)$, and $b' = \frac{lt' + CT}{l + C}$, from whence any of the dimensions can be obtained, the others being assumed

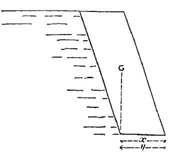


where l = length of wall between counterforts
t = breadth of ,,
C = length of counterforts
T = breadth of ,,

If l be assumed $= 3t$, $C = t$ and $T = 2t$, then

$$t = \sqrt{\frac{4}{7}\,b'} = 75\,b$$

III For a rhomboidal wall, the maximum stability is where the wall reclines, that is, when the vertical through the centre of gravity cuts the interior angle of the base



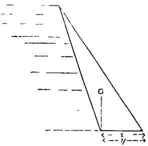
in equation (4) $A = h\,b$
$A' = h\,x$
$y = x$

$$\frac{h\,b^2}{2} = h\,x^2 \text{ and } x = \sqrt{\frac{b^2}{2}} = 707\,b^*$$

IV Also in a reclining triangular wall the maximum stability to

* In this, and the following, I neglect the changes in value produced by the slope of the back of wall, and assume the plane to be vertical

resist forward oversetting will be when $y = x$, in equation (4), and as



$$A' = \frac{h\,x}{2} \qquad \frac{h\,b^2}{2} = \frac{h\,x^2}{2}$$

and $\therefore x = b$

The sections of these walls are constructed as follows —For rhomboidal wall, *Fig a*, set off $a\ b = x$, at b erect a perpendicular $b\ c = h$, join $a\ c$ and draw $b\ d$ parallel to $a\ c$, then $a\ b\ c\ d =$ required wall

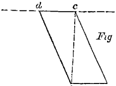


Fig a

For triangle, *Fig b*, proceed as above, and the face of the wall is a line from (a) passing through bisection of $c\ b$ Join $d\ b$, for back of wall, then $a\ b\ d$ is the required wall

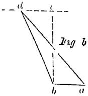
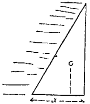


Fig b

V A triangular wall with plumb face, $A' = \frac{h\,x}{2}$ and $y = \frac{1}{3}\,x$,

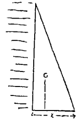


therefore equation (4) becomes $\frac{h\,b^2}{2} = \frac{h\,x^2}{2 \times 3}$ $\therefore x =$

$$\sqrt{3\,b^2} = 1.73\,b$$

VI Or with a plumb back, A' as above, and $y = \frac{2}{3}\,x$,

whence (4), $\frac{h\,b^2}{2} = \frac{2\,h\,x^2}{3 \times 2}$ $\therefore x = \sqrt{\frac{3}{2}\,b^2} = 1.23\,b$



VII Any triangle such as in *Fig* 2, whose face batter r, in terms of the height, is given, has,

$A' = \frac{h\,x}{2}$, and $y = \frac{x}{3} + \frac{r\,h}{3}$ because

$$\text{H G} + \text{H}\,t = y$$

but $\text{H G} : \frac{2}{3}h :: \frac{1}{2}x : h$

$$\text{H G} = \frac{x}{3}$$

and $\text{H}\,t = \frac{r\,h}{3}$

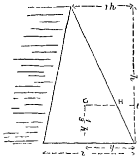


Fig 2

In equation (4), with the above values of $A'y$, we have

$$\frac{h\,b^2}{2} = \frac{h\,x}{2}\left(\frac{x}{3} + \frac{r\,h}{3}\right), \text{ and } x^2 + r\,h\,x = 3\,b^2, \text{ a quadratic,}$$

whence

$$x = \sqrt{3\,b^2 + \left(\frac{r\,h}{2}\right)^2} - \frac{r\,h}{2}, \qquad (5)$$

where

x = breadth of base of any triangular wall with a given face batter, b and h as before, and

r = the fraction representing batter of wall face, in terms of the height

The equation for the moment of stability of this wall = M'

$$= \text{W}_1\left(\frac{h\,x^2 + h^2\,x\,r}{6}\right) \qquad (6)$$

VIII A trapezoidal wall, such as *Fig*, 3, by equating moments we get—

$$\frac{\text{W}_1\,h\,b^2}{2} = \frac{\text{W}_1\,h\,z^2}{3} + \text{W}_1\,h\,z\,t + \frac{\text{W}_1\,h\,t^2}{2}$$

$$\therefore b^2 = \tfrac{2}{3}z^2 + 2\,z\,t + t^2$$

Where z = portion of the base due to batter,

t = thickness of top

x = breadth of base, $= z + t$

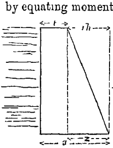


Fig 3

If the batter of face be given, $z = r\,h$, the breadth of top is then required, and is, $t = \sqrt{b^2 + \frac{z^2}{3}} - z$, and $z = \sqrt{\frac{3}{2}\,b^2 + \frac{3}{4}\,t^2} - \frac{3}{2}\,t$, when the breadth at top is fixed

IX Also in one, as in *Fig* 4, where the back batters and the face is plumb, $t = \sqrt{b^2 - \frac{z^2}{12}} - \frac{z}{2}$, and

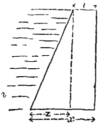


Fig 4

$$z_1 = \sqrt{3\,b^2 - \frac{3}{4}\,t^2} - \frac{3}{2}\,t$$

In these two cases, if $t = 0$, z and z_1 become $= x$ in cases *Figs* 4 and 5.

X In one such as shown in *Fig* 5, let z_1 = part of base due to batter at back, $z = r\,h$

Then equating stabilities we have $\frac{h\,b^2}{2}$

$$= \frac{hz^2}{3} + h\,t\left(\frac{t}{2} + z\right) + \frac{h\,z'}{2}\left(\frac{z'}{3} + t + z\right)$$

and t and z being given

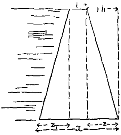


Fig 5

$$z_1 = \sqrt{3\,b^2 + 25z^2 - (75\,t^2 + 15\,t\,z)} - 15\,(t + z), \text{ and } x = z + t + z_1$$

This last section will not be found of much value, and a section as in *Fig* 6, will be superior

The above equations I recapitulate in the following tabular form, giving also the equations by which x may be got from the data direct, instead of through the medium of the standard wall

TABLE III.

(Giving values of x)

P = Horizontal pressure against wall, obtained either by Neville's tables or by formula, and is independent of shape of mass retained	$\frac{W}{W_1} = \frac{\text{Weight of mass retained}}{\text{Weight of masonry}} = \frac{S^\circ}{S_1}$ and $\sqrt{\frac{1}{S_1}} = 8\sqrt{\frac{1}{W_1}}$
h = Height of wall taken vertically	$\theta = \angle$ of natural slope $\alpha = 90^\circ - \theta$
b = Breadth of wall, when vertical and rectangular	r = Fraction of height representing batter of wall as $\frac{1}{8} h = r\,h$
	x = Breadth of base of any wall

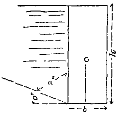
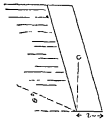
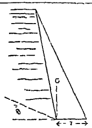
Figures of Walls	Values of x the breadth of base of walls, as in Column 1			
	When compared with standard	Generally for any ascertained horizontal pressure	For water	For earth with top horizontal
1	2	3	4	5
	b	$8\sqrt{\frac{P}{W_1}}$	$4.5\,h\sqrt{\frac{1}{W_1}}$	$58\,h \tan\frac{1}{2}\alpha\sqrt{\frac{W}{W_1}}$
	$7\,b$	$58\sqrt{\frac{P}{W_1}}$	$3.2\,h\sqrt{\frac{1}{W_1}}$	$41\,h \tan\frac{1}{2}\alpha\sqrt{\frac{W}{W_1}}$
	b	as in	case	No 1

TABLE III—(*Continued*)

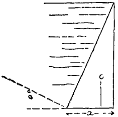
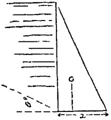
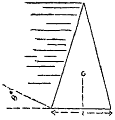
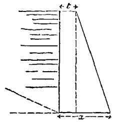
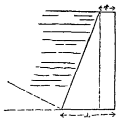
Figures of Walls	Values of x the breadth of base of walls as in Column I			
	When compared with standard.	Generally for any ascertained horizontal pressure	For water	For earth with top horizontal
1	2	3	4	5
	$1\ 7\ b$	$1\ 4\sqrt{\frac{P}{W_1}}$	$8\ h\sqrt{\frac{1}{W_1}}$	$h \tan \frac{1}{2} a \sqrt{\frac{W}{W_1}}$
	$1\ 2\ b$	$\sqrt{\frac{P}{W_1}}$	$5\ 6\ h\sqrt{\frac{1}{W_1}}$	$71\ h \tan \frac{1}{2} a \sqrt{\frac{W}{W_1}}$
	$\sqrt{3\ b^2 + \left(\frac{r\ h}{2}\right)^2} - \frac{r\ h}{2}$	$\sqrt{\frac{2P}{W_1} + \left(\frac{r\ h}{2}\right)^2} - \frac{r\ h}{2}$	$\sqrt{\frac{62\frac{1}{2}\ h^2}{W_1} + \left(\frac{r\ h}{2}\right)^2} - \frac{r\ h}{2}$	$\sqrt{\frac{W}{W_1} h^2 \tan^2 \frac{1}{2} a + \left(\frac{r\ h}{2}\right)^2} - \frac{r\ h}{2}$

TABLE III—(*Continued*)

Figures of Walls	Values of x the breadth of base of walls, as in Column 1			
	When compared with standard	Generally for any ascertained horizontal pressure	For water	For earth with top horizontal
1	2	3	4	5
	$\sqrt{1\cdot5\,b^2 + \cdot75\,t^2} - \frac{t}{2}$	$\sqrt{\frac{P}{W_1} + \cdot75\,t^2} - \frac{t}{2}$	$\sqrt{\frac{31\frac{1}{4}\,h^2}{W_1} + \frac{3}{4}t^2} - \frac{t}{2}$	$\sqrt{\frac{h^2 W}{2 W_1}\tan^2 \tfrac{1}{2}\alpha + \cdot75\,t^2} - \frac{t}{2}$
	$\sqrt{3\,b^2 - \cdot75\,t^2} - \frac{t}{2}$	$\sqrt{2\frac{P}{W_1} - \cdot75\frac{t^2}{2}} - \frac{t}{2}$	$\sqrt{\frac{62\cdot5\,h^2}{W_1} - \frac{3}{4}t^2} - \frac{t}{2}$	$\sqrt{\frac{h^2 W}{W_1}\tan^2\frac{\alpha}{2} - \frac{3}{4}t^2} - \frac{t}{2}$

It appears from deductions in pp 320 321, that the proper thickness of an average retaining wall with vertical faces will be, for water $= \cdot36\,h$, and for earth—loose earth $= \cdot25\,h$ These breadths are not far from the rules of practice, and I think may be taken as safe guides, doubtlessly we see weaker walls stand, but we often hear of failures, and although by special consolidation, and by placing the earth in counter-sloping layers, we may much reduce the values of θ; and, by-the-bye, increase those of W, yet the possibility of water getting behind the work, and saturating the stuff, should I think be

looked to as a possible contingency, and that no walls should, except under special circumstances, be designed less than I have assigned to those in the attached diagram

The triangular sections in this diagram diminish at the top to a point, but in practice walls would be designed of a practical breadth, which would give an additional stability, and they should also batter at the back in steps, as shown in *Fig* 6, as there is a very considerable vertical element of the pressure, which tends to the stability of the wall It appears that this vertical force bears a large proportion to the horizontal pressure, hence retaining walls should have greater spread given to their foundations than the mere weight of the walls themselves would demand

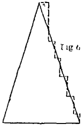


Fig 6

Return walls and wing walls of bridges, usually have not the full triangle of earth pressing on them, hence a less section of wall should suffice, their breadth if no water is allowed behind them need seldom exceed, for a vertical rectangular section, the proportion of $\frac{h}{5}$

Although it is argued above that 25 h will be the average breadth of a vertical rectangular retaining wall, to resist the horizontal pressure of a bank of loose earth, whose top surface is level with the top of the wall, the friction between the earth and back of wall being neglected , yet this can only be taken as a rough practical guide when no exact data exist Should, however, the variables in the formula $b = 578\,h \tan\frac{90-\theta}{2}\sqrt{\frac{W}{W_1}}$ be obtainable by actual observation, the following table will be found to facilitate the calculation of the proper breadth of wall

K, K, K, &c , of the table represent $578 \tan\frac{90-\theta}{2}\sqrt{\frac{W}{W_1}}$ and are co-efficients of h in the general formula, whence $b = h$ K, for vertical rectangular walls

When $\theta = 0$, K is the co efficient for water pressure

TABLE OF CO-EFFICIENTS OF h, FOR FINDING BREADTH OF STANDARD WALLS, $b = h$ K

Top of Bank Horizontal

Ratios of $W - W_1$	Fracts	$\frac{1}{1}$	$\frac{1}{11}$	$\frac{1}{12}$	$\frac{1}{13}$	$\frac{1}{14}$	$\frac{1}{15}$	$\frac{1}{16}$	$\frac{1}{17}$	$\frac{1}{18}$	$\frac{1}{19}$	$\frac{1}{20}$	$\frac{1}{21}$	$\frac{1}{22}$	$\frac{1}{23}$	$\frac{1}{24}$	$\frac{1}{25}$
	Decs	1	909	833	769	714	667	625	588	555	526	5	476	455	435	416	4
Angles of Repose $\theta°$		K															
0°	K	577	55	·527	506	488	472	456	443	43	419	408	399	389	381	373	365
30°		334	317	304	292	282	272	263	256	248	242	235	230	224	220	215	211
31°		327	311	298	286	276	267	258	251	243	237	231	225	22	216	211	207
32°		320	305	292	281	270	261	253	245	238	232	226	221	216	211	206	202
33°		314	299	286	275	265	256	248	240	234	228	222	217	212	207	203	198
34°		307	293	280	269	260	251	243	236	229	223	217	212	207	203	198	194
35°		3	286	274	263	254	245	237	230	224	218	212	207	202	198	194	19
36°		295	28	268	258	248	240	232	225	219	213	208	203	198	194	19	186
37°		288	274	262	252	243	235	227	221	214	209	203	199	194	190	186	182
38°		282	268	257	246	238	230	222	216	209	204	199	194	189	185	182	178
39°		276	262	251	241	232	225	217	211	205	199	194	19	185	181	177	174
40°		269	256	245	235	227	219	212	206	2	195	190	185	180	177	173	170
41°		263·	250	240	23	222	215	207	202	196	192	186	181	177	173	170	166
42°		257	244	234	225	216	21	202	197	191	186	181	177	173	169	165	162
43°		251	239	229	220	212	205	198	192	187	182	177	173	169	165	162	158
44°		245	233	223	214	206	2	193	188	184	177	172	169	164	161	158	154
45°		239	227	218	209	202	195	188	183	178	173	168	165	161	157	154	151

Example.—The height of a loose earthen bank with horizontal top is 20 feet, its angle of repose is 34°, the weight of a cubic foot is 112 lbs, what will be the breadth (b) of a vertical faced rectangular rubble wall, whose weight per cubic foot is 150 lbs, to retain the bank?

$$\theta^\circ = 34^\circ, \frac{W}{W_1} = \frac{112}{150} = \frac{1}{1 \cdot 34}$$

In left vertical column we find angle of repose 34°, and in top column of ratios $\frac{W}{W_1}$ $\frac{1}{1 \cdot 3}$, and at intersection $K = \cdot 269$, therefore breadth,

$$b = h\,K = h\ \cdot 269 = 5 \cdot 38 \text{ feet}$$

More minute accuracy may be obtained by interpolation of co-efficients the mean of co-efficients for angles 30° and 31°, giving that for 30½°, and ratios of $\frac{1}{1 \cdot 1}$ and $\frac{1}{1 \cdot 2}$ giving that for $\frac{1}{1 \cdot 15}$

In the case above the ratio $\frac{1}{1 \cdot 35}$ would be closer to the actual ratio $\frac{1}{1 \cdot 34}$ than $\frac{1}{1 \cdot 3}$, we have therefore by interpolation the co-efficient for the former $= \frac{\cdot 269 + \cdot 260}{2} = \cdot 264$, hence the breadth of the wall would have been more exactly 5·28 feet

This is the breadth for mere equilibrium, and it remains to decide what margin is to be allowed to the wall for stability

I shall only remark here that in making this allowance the following points are to be noted—

That the stability is decreased by any saturation of the earth retained

That the stability of the wall is increased by the friction of the earth against its back

That it is increased by the tenacity of the mortar, joining the wall to its foundation courses

That it is increased by precautions for thorough drainage at the back, by filling in with chips and shivers of the stone used in building, and by the arrangement of the earth in punned layers

No XXXVI

CHENAB SAW-MILLS

Design for erecting SAW-MILLS *on the river Chenab, in the Punjab By* J. D SMITHE, ESQ, C E, *Executive Engineer, Baree Doab Canal Workshops*

Position of Proposed Site —The site selected for the erection of Saw-mills is on an island on the right bank of the river Chenab, close to the boundary of British and Jummoo territory, and where the boundary line runs North-west, along the right bank of the Meean Khor

The Meean Khor —The Meean Khor is a stream which, taking out of the Chenab right bank, joins the main river about 12 miles lower down, the island thus formed is much cut up by several other streams into smaller islands

The Bhag —The Bhag takes out of the Chenab below the Meean Khor, but the land between the Chenab and Bhag is covered in floods, and unsuited for building on

Nature of Site —This large island, lying between the Meean Khor and the Chenab, is well above the river, it has several villages upon it towards the lower part, but near the proposed site of Saw-mills there is only one small village called Keree, composed of a few wretched huts This village will probably not interfere with the contemplated works There are a few small patches of cultivation about here, but nothing worth taking into consideration, also a large quantity of land below the village not cultivated

Reasons for Selection of Site —The country bordering the Chenab was well examined before fixing on the proposed site The Maharajah of

Jummoo's boundary crossed the Chenab rather low down, and rendered it unadvisable that any place should be selected beyond it. It would have been advantageous on the other hand to keep as low down the river as possible, and near the large roads leading to Sealkote and Wuzeerabad, for facilities of catching and transport, but this could not be done without interfering with villages and cultivated land, and giving a very large mill channel, as well as a secondary channel from the river to look after and control. The slope of the country and river lessens rapidly as we get lower down, and the shingle disappearing gives place to sand, which in the river and secondary channels become quick sands, we recede also from our building material. These matters being kept in view the proposed place was selected. The field work subsequently showed it possessed natural advantages, and taking all matters into consideration meets most of our requirements of a site for the erection of Saw-mills.

Levels of Island.—The sheet of sections forwarded will show the nature of the levels, it will be seen that the difference of level of surface of water at head of island, Z, and head of inlet to mill, E, is 11.90 feet, affording ample opportunity of securing a certain depth of water at the inlet, the difference between E and natural surface of land at narrowest part of the island is 2.71, thus showing that the fall is into the river and not from it.

Fall available for a Water-wheel.—The levels of beds of the streams, Meeran Khor, at E, and Ghug, near T, being the proposed inlet and outlet, show that the site of the inlet bridge is 12.59 above outlet. This fall is ample for all our wants, and would give much more power than is needed for the mill.

Supply of Water.—A sufficiency of water can always be ensured for the mill, and the nature of the point of island, and its position with regard to the right bank of the Chenab, afford great facilities for controlling the supply, should there be naturally either too little or too much.

Controlling the River.—Should the river show any tendency to leave the front of the island near A, a small spur thrown out diagonally up-stream would give ample water. The bed is all shingle, and medium sized boulders afford material on the spot for the spur. This probably will require to be done eventually. On the contrary should the river come over to the right bank too much, or show signs of going down the Meeran Khor or the Jago above it, small shingle spurs pushed out on the right bank

would protect them from the force of the river, but instead of enlarging these channels I believe the natural tendency of the river is to cut across the salient angle on the left bank of the Chenab, there being numerous large channels across it now with very low land between them

Advantages of site for Catching and Landing timber —The proposed site possesses great advantages in having secondary channels easily controlled on either side, so that it is not so exposed to the eroding action of the streams, as it would be if subject to the full force of the main stream of the Chenab, it gives us a length of water frontage on two sides of nearly 12,000 feet, for floating down large quantities of timber and landing it easily, and this is an immense advantage over a site bounded by main stream of river A large body of water running at a high velocity, such as that of the Chenab opposite this place, would sweep much of our timber past before it could be secured and landed

Storing and Despatching —As will be seen on reference to plan of the island, &c, the piece of ground is of some extent, and gives us ample space for landing and stacking a large quantity of timber, both in logs above the mill, and in scantling below the mill The Bhag below the tail race is better suited for making up rafts in, than the main stream, as it meets the Chenab lower down, it provides water carriage for the rafts of sawn wood to any place on the Chenab below this

Catching places with regard to site of Mill —The position for the mill, with regard to length of river and catching depots is well situated Of 30,000 logs caught in one season, 25,000 were secured above this island at Aknoor and Reasi With mills at work it would of course be advantageous to catch as much as possible above them and send it down afterwards when the river is moderate in height and the timber controllable With this in view no doubt nine-tenths of the timber could be sawn up by the mills, (and which if carried past by floods would not be available for the mills,) and could be disposed of in logs as at present

Building Material —With regard to materials for building, they are close at hand, boulders close under the surface, and in beds of streams and river; lime-stone collected and burnt, one-fourth of a mile from site The upper soil is shingle and earth, but this is of no thickness

Description of Wheel —The motive power is Water, which will work an Under-shot Wheel The principle of the Wheel is that known as Poncelet's, the chief feature of which is the curved floats for the water to exert

itself upon; this is considered a great improvement over the ordinary radiating floats of under-shot wheels; it will give 75 per cent of the effective power of water usually, and more than double the power for the same amount of water, which an ordinary radial under-shot wheel requires.

Size of Wheel.—The wheel is to be 10 feet diameter, width 8 feet, area of sluice, $8.0 \times 0.6 = 4.80$; with head of water for working, 5.80.

Calculation of Power.—The following will show particulars connected with the wheel:—

$$h = 5.80 - \frac{0.6}{2} = 5.5 \quad V = .95\sqrt{2gh}$$

$$= .95\sqrt{64.4 \times 5.5}$$

$= 17.878$—velocity of water in channel

$v = \dfrac{V}{2} = 8.939$—velocity of rim of wheel

$$R = \frac{v}{3.1416 \times d} \times 60$$

$$= \frac{8.939}{3.1416 \times 10} \times 60$$

$= 17.04$ revolutions of wheel per minute

$D = SV = 17.878 \times 4.80$

$= 85.81$—discharge of water per second in cubic feet

$P = \dfrac{D \times 62.5 \times H}{550} = 53.6$ nominal horse power

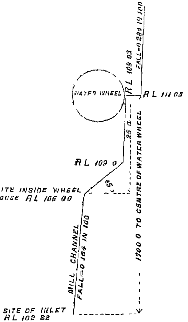
75 per cent. of which $= 40.2$ effective horse power

Distribution of Power.—The power of the wheel will be thus disposed of—

	11	horse-power	for No. 1 frame
	10	" "	for No. 2 "
	8	" "	for No. 3 "
	8	" "	for two circular saws
Total,	37		

But the three frames and two circular saws can under no circumstances be all kept working together. Stoppages to regulate saws, adjusting timber, removing it and bringing up new wood to saws, will keep one standing whilst the others are working, and as there is no occasion for more power than is required, there being no probability of any other machinery ever being attached to the wheel, I consider 40 horse-power as sufficient. If needed, however, more power can be obtained by increasing the head of water and the opening of sluice without altering any part of the machinery; these points have been kept in view and provided for.

Mill Channel.—The slope of mill channel being 0 164 in 100, the quantity of water required will give a depth of about 2 5 in the channel There is a point in the channel worth noting Instead of excavating it at a uniform slope from site of bridge to lower point of outlet at wheel, the bed has been kept up, and a sudden slope given into the cistern at the wheel This reduces the slope in the channel very much, and enables it to be made in natural soil without any boulder paving, it keeps the width of channel uniform and prevents the ground being cut up by a very wide channel, which otherwise becomes necessary when side slopes are kept uniform and the depth of excavation increases towards the wheel A wide mill channel is objectionable through land required for stocking large quantities of timber near the mill The plan proposed also saves excavation



Side Channel for Escape.—An escape channel has been provided for use when the water-wheel is standing The water in the Punjab rivers for many months in the year is so highly charged with silt that it becomes a nuisance and source of expense when allowed to settle, as it does in a mill channel when a head of water is required, the water being held up and only escaping in a small body at one part, silt falls rapidly, and nothing but digging it out will remove it The side channel will be opened whenever the water-wheel is not at work, and grooves have been provided for planking at the inlet under the end wall of wheel-house

Regulating.—The escape channel under ordinary circumstances will be planked up to a height of 6 feet above the bed, and forms an overfall or (weir) for any sudden accession of water, the weir can be regulated by the removal of planks, and the water thus kept at a constant height in the

wheel cistern The gate at the inlet to mill channel shuts off the communication with the river when desirable

Machinery —Simple and Strong —In the design of the water-wheel and gearing, simplicity combined with effectiveness have been kept in view, each part is amply strong and no special repairs are likely to be needed As it is not probable anything beyond the first conversion of timber into scantlings will ever be required here, no provision for future extensions have been taken into consideration

---

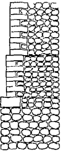
SPECIFICATION

There are three buildings for the Saw-mills, viz, Wheel-house, Vertical Sawing-room, and Circular Sawing-room

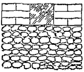
Masonry in Foundation —The foundations of all the buildings are of boulder masonry in mortar, they vary in depth according to position, the only portion below the ground line faced or built fair on one side, is the following —The inside of wheel-house above wheel seat, from lower floor to ground level, revetment walls at escape, including mill and crest wall, also the diverging walls

Superstructure —The whole of the superstructure is to be faced boulder work in mortar, except arches and other exceptions, hereinafter noted, all right angles being brought up true with half bricks, and all off-sets with half brick-on-edge, walls to have a fair face of split boulders, and built true

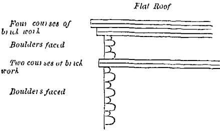
Section of walls showing the brick angles worked into the boulders



Tops of all walls of buildings to have a few courses of brick-work under and about wall plates, ends of kurries, beams and trusses of framed roof.

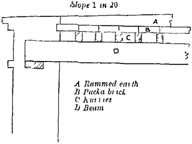


Section of top to superstructure

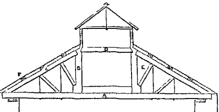


All arches to be built of good pucka bricks in mortar, a cornice and string course to run round buildings with flat roofs, as per sketch in margin

Roofs Flat.—The roofs of Wheel-house and Circular saw-house to be of beams and kurries, with pucka brick laid flat, in mortar, and covered with well beaten earth, mixed with *bhoosa* (chopped straw), finished to a slope of 1 in 20, all roofing beams to be cut with a camber of 0 1 in 20 feet, small ventilators to be built at intervals on the flat roof



Roof Trussed and Slated.—For the Vertical saw-room the roof is framed, with ventilators along the ridge Over the purlins, planking 0 10 inches thick is nailed, and on this is laid the slates 20 × 10 inches, with two-thirds lap, dimensions of scantling, as shown in the margin The ventilators to be slated similar to the roof, sides sheet iron, open, with a sheet iron ridge cap



Span 35 feet
Scantlings of timber —

		″	″
A	Tie beams,	12	× 6½
B	Queen posts,	8	× 6½
C	Principle rafters,	8	× 6½
D	Straining beam,	9	× 8
E	Struts,	6½	× 4
F	Purlins,	5	× 3

Boarding between Wall Pillars.—The east side of the vertical saw-house as far as the wheel-house, and west side of the circular saw-house, to be masonry, pillars filled in between with wood-work, as shown in drawing The timber to be framed so as to form *chokuts* for doors, the upper part and sides to be filled in with boards 0 10′ thick nailed on to the framing, the upper board overlapping, the lower one 0 10′ this extends up to the roof, and saves arching and masonry over the door-ways.

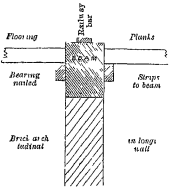
Doors Glazed.—The upper portion of large end doorways to be similarly finished to save framing a circular headed door. All doors are square headed, with glass in the upper part, to admit light; all the doors are double boarded and framed for panel.

Floorings.—The whole of the three buildings are to be floored with 0.25′ planks, laid in narrow pieces of 0.5′ wide, nailed to kurries and beams, as required. The beams are over the cistern in the wheel-house, and the vaults in circular and vertical saw-rooms; the remainder of the flooring to be on kurries. In the vertical saw-room, the beams are laid along the top of the longitudinal brick walls; in the circular saw-room they are supported at the ends by the side walls; in the centre portion on cast-iron bracketed caps, on wooden pillars; all the floorings to be laid with close joints to prevent dusting.

Pillars in Vault.—In the vaults are good sound brick masonry pillars, with hoop iron bond for carrying the plummer blocks, and shafting for communicating the power.

Foundation Seats for Machine.—The seats for foundation plates for the vertical saw-frames are also to be built of the best description of brick-work with hoop iron bond; great care must be taken in building these pillars and foundation seats, and the holding down bolts must be carefully provided for.

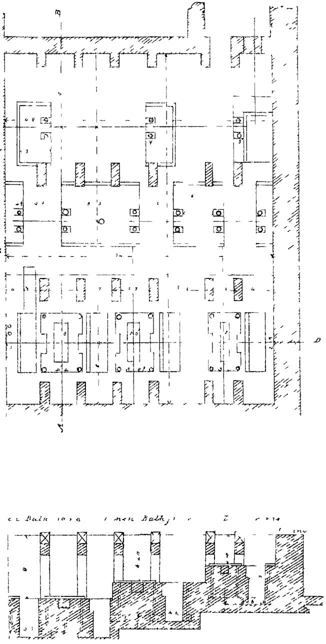
Walls for Railway Vertical Saw-vaults.—Longitudinal arched walls



are built in the vertical saw-vaults, of good brick masonry in mortar, 1 foot thick; on these are laid stout beams of timbers for carrying the railway and carriages which convey the logs up to the saws whilst being cut. The planked flooring is continued between these beams, and carried on bearing strips nailed to the beams.

Passage for Shaft.—A passage runs from the vertical to circular saw-vault, in which is the shafting for communicating the power to drive the circular saws; two archways from this passage lead into the circular saw-vault, the leather driving belt passing through the first archway, across the passage; and in line with

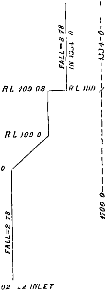
PLATE XLIII



wall of vertical saw-house, an arch is thrown to strengthen the ls The planked flooring is continuous over all

-wheel Seat —The seat for water-wheel is to be built of good brick with hoop iron bond, great care being taken to render it one solid aces are left for holding down bolts for plummer blocks it is fin- th brick-on-edge "herring bone" on top

itor at Inlet of the Mill Channel —The regulator inlet at head of and is of the same description of masonry as the mill, boulders in partly faced and finished with brick-on-edge at top The arch is f 60° of 8 0 feet span for a depth of water of 2 4 feet on sill of uilt of three-half brick rings in mortar, the floor of bridge under oe boulders in mortar. The left bank up-stream revetment wall is gle of 50° to centre line of mill channel, that being the general of the present bank Grooves are provided for a gate at the m face of bridge to shut off the water, and a small portion of n dry boulders forms a flooring above and below it, converging provided for contracting the width to 4 feet, (the width of chan- l also for finishing off the side slopes



Mill Channel —Cross and longitudinal sections of mill channel are shown in the drawings, the bottom width above wheel house to be 4 feet, to be increased at wheel-house cistern to width of wheel (8 feet) Below the wheel-house, the bottom width decreases again from 8 to 6 feet in a length of 50 feet, and is continued at this width to the end Below wheel-house, side slopes to be carried up in dry boulder paving to ground line of vertical saw-house, below which the slope widens out to $1\frac{1}{2}$ to 1, the paving stops at end of curve The side slopes of mill channel, from regulator inlet to escape at wheel-house to be also $1\frac{1}{2}$ to 1.

Escape Channel —The escape channel round wheel-house to be paved with dry boulders, the left side at a slope of one-

half to 1, the right side is formed by the foundation wall of wheel-house being carried up with a batter in pucka boulder masonry, the wall being widened out below to allow of this being done, and also to stand the action of the water along it At the head of the escape channel, the fall into it from the upper channel is provided for by a well, and the water is regulated by planks put into the grooves provided at the face of the two bridges At the end a cross wall is built 1 foot high The escape channel has a slope of 0 25 in 100

Converging Walls —Converging walls are provided where it is necessary to finish the earthen side slopes against the masonry, these walls slope, in plan, 5 to 1 in width, and in elevation, to level of bed, they are of boulders faced above ground, and finished on top with one brick-on-edge

Water-Wheel —The water-wheel is to be 20 feet diameter and 8 feet wide, the shaft is square of boiler plate, rivetted with angle iron, along the inside at the centre where the boiler plates are joined, there is a cast-iron square T piece inside, the shaft is made in two lengths (to suit length of plates) and joined on the cast-iron T piece At either end a casting is rivetted inside the shaft, and forms a boss outside for carrying the arms The journal is of cast-iron turned and fitted in the end casting, being firmly fastened on with four wrought-iron keys Places are cast on the boss for carrying the arms, which are of wood, fastened to the boss with bolts and nuts The shrouding is of thick sheet iron, width of which is one-third the head of water, or 2 feet The floats are also of sheet iron, curved and fastened to shrouding by angle iron rivetted on it, small screw bolts fasten the sheet iron floats to the angle iron at sides The floats are in two lengths forming the width of the wheel, the division (or centre shrouding) being carried by intermediate arms halved across the centre of the shaft

Gearing —One end of the wheel shaft carries a large spur wheel with wooden teeth, working into a cast-iron pinion (dressed teeth) on the long shaft which runs through an archway inside the wall into the vault, cast-iron pulleys on this shaft carry the leather driving belts for communicating motion to the machinery

Speeds —The water-wheel is to make 17 revolutions per minute —

No 1	frame,	108	strokes	per minute
No 2	„	129	„	„
No 3	„	114	„	„

The Circular Saws, 3 feet diameter, make about 500 revolutions, or travel about 4,700 feet per minute

Sluice and Working it.—The sluice for letting on and shutting off the water in the wheel-house is built up of planking and iron straps bolted together, it is suspended from the back by two radial arms fastened to iron plates, built into the floor of the cistern The rack above the floor of wheel-house is acted upon by toothed gearing and the sluice raised, a counterweight being attached to it by a chain running over a wheel under the floor The radial arms allow the sluice to raise a certain amount as required for the passage of the water into the wheel, a wide strip of leather fastened to the side walls of cistern by sheet iron strips is kept close against the sheet by the pressure of the water, and a fair joint which allows little water to escape is formed

Circular Saw Benches.—Two circular saw benches are provided, the centre portion carrying the saw being of cast-iron, the lengthening at either end being timber framed and planked on top The saws are arranged to rise and fall as desired, varying with the thickness of wood to be cut, the belts for working the saws come through openings in the floor close to the pulley Levers are provided for passing the belts from fast to loose pulleys, and *vice versâ*, for each frame and the two circular saws

Gearing under Ground.—All gearing and pulleys for carrying belts are kept under the floor in the vaults and wheel-house, this leaves the floor clear for work, allows the superstructure being made light, and prevents accidents to workpeople employed about the building

Leather Driving Belts.—There are seven large belts required, one for driving each frame and three from the main shaft to countershafts, one also from the longitudinal shaft to take power into the circular saw vault These belts to convey the power must be well made of the best leather procurable Five of them will be about one foot wide of three thicknesses of leather sewed together, with five rows of leather through the whole length The other two will be a trifle less in width, but of the same thickness and construction For the circular saws four belts are required, 7 and 9 inches in width, with double thickness of leather, and four rows of sewing, none but the best leather to be used in any of these belts

Fitting Machines to Wheel.—Great care must be taken in erecting the water-wheel and vertical saw frames, also in putting the shafting into its place, the amount of attention that is bestowed on these works will very

soon show itself after the machinery once commences to work If erected carefully, the wear of brasses and journals will be imperceptible, the shafting will run smooth and the machines work without noise

---

ABSTRACT OF ESTIMATE

Vertical Saw Room

c ft		rs
10,194 64	Masonry, boulder, in foundations, at Rs 9 per 100,	917 5176
698 00	Masonry, brick, plain, foundations, at Rs 20 per 100,	139 6000
119 38	Masonry, brick arching, foundations, at Rs 28 per 100,	33 4264
568 75	Masonry, boulder, faced, in plinth, at Rs 10 per 100,	56 8750
142 19	Masonry, brick, plain, in plinth, foundations, at Rs 20 per 100,	28 4380
4,450 46	Masonry, boulder, faced, in superstructure, at Rs 11 per 100,	489 5506
1,038 00	Masonry, brick, plain, in superstructure, at Rs 20 per 100,	207 6000
508 95	Masonry, brick, arching, in superstructure, at Rs 28 per 100,	142 5060
s ft		
3,519 00	Flooring, wood work, including beams, at 12 as per 100,	2,639 2500
8,216 00	Roofing, at Rs 65 per 100,	5,340 4000
924 00	Doors, at Rs 1,	924 0000
1,536 00	Filling in doorways, wood work, at 12 as,	1,152 0000
c ft		
14,137 50	Excavation in water, at Rs 8 per 100,	113 1000
	Total,	12,184 2636

Wheel House

c ft		
3,765 48	Masonry, boulder, in foundation, at Rs 9 per 100,	338 8887
343 12	Masonry, brick, plain, foundation, at Rs 20 per 100,	68 6240
82 44	Masonry, arching, foundation, at Rs 28 per 100,	23 0832
277 50	Masonry, boulder, faced, in plinth, at Rs 10 per 100,	27 7500
69 37	Masonry, brick, plain, at Rs 20 per 100,	13 8740
1,452 26	Masonry, boulder, faced, in superstructure, at Rs 11 per 100,	159 7486
570 00	Masonry, brick, plain, in superstructure, at Rs 20 per 100,	114 0000
157 00	Masonry, brick, arching, in superstructure, at Rs 28 per 100,	43 9600
s ft		
293 00	Flooring, brick-on-edge, at Rs 30 per 100,	87 9000
490 00	Flooring, wood work, including beams, at 12 as,	367 5000
320 00	Doors, at Rs 1,	320 0000
1,118 00	Roofing, at Rs 40 per 100,	447 2000
c ft		
14,403 12	Excavation in water, at Rs 8 per 1000,	115 2249
	Total,	2,127 7584

Vertical Saw Vault

c ft		Rs
3,329 25	Masonry, boulder, in foundation, at Rs 9 per 100,	299 632
1,682 12	Masonry, brick, plain, in superstructure, at Rs 20 per 100,	336 424
362 85	Masonry, brick, arching, in superstructure, at Rs 28 per 100,	101 598
828 00	Masonry, boulder, dry, in flooring, at Rs 10 per 100,	82 800
s ft		
1,680 00	Flooring, wood-work, including beams, at Rs 1,	1,680 000
c ft		
16,560 00	Excavation in water, at Rs 8 per 1000,	132 480
	Total,	2,632 934

Circular Saw House

c ft		
3,064 76	Masonry, boulder, in foundation, at Rs 9 per 100,	275 828
229 25	Masonry, brick, plain, foundation, at Rs 20 per 100,	45 850
352 50	Masonry, boulder, faced, in plinth, at Rs 10 per 100,	35 250
88 12	Masonry, brick, plain, in plinth, at Rs 20 per 100,	17 624
2,117 54	Masonry, boulder, faced, in superstructure, at Rs 11 per 100,	232 929
1,662 11	Masonry, brick, plain, in superstructure, at Rs 20 per 100,	332 422
235 62	Masonry, brick, arching, in superstructure, at Rs 28 per 100,	65 973
833 00	Masonry, dry, boulder, in flooring, at Rs 10 per 100,	83 300
s ft		
1,225 00	Flooring, wood work, including beams, at Rs 1, ..	1,225 000
420 00	Doors, at Rs 1,	420 000
90 00	Filling in doorways, wood work, at 8 as,	45 000
1,364 75	Roofing, at Rs 40 per 100,	545 900
c ft		
1,681 65	Excavation, at 8 as per 1000,	13 453
	Total,	3,338 530

Tail Race

c ft		
1,337 75	Masonry, boulder, in foundation, at Rs 9 per 100,	120 397
226 00	Masonry, brick plain, foundation, at Rs 20 per 100,	45 200
12,888 00	Excavation in water, at Rs 10 per 1000, ..	128 880
	Total,	294 477

Regulator Inlet.

c ft.		
4,746 67	Masonry, boulder, in foundation, at Rs 9 per 100,	427 200
73 12	Masonry, brick, plain, foundation, at Rs 20 per 100,	14 624
178 62	Masonry, brick, arching, foundation, at Rs 28 per 100,	50 013
1,451·08	Masonry, boulder, faced, in superstructure, at Rs 13 per 100,	188 640

c ft		Rs
338	Masonry, dry boulder paving, at Rs 10 per 100,	33 8000
9,479 45	Excavation in water, at Rs 10 per 1000,	94 7945
	Total,	509 0728

Escape Channel

c ft		
2,869 82	Masonry, boulder, in foundation, at Rs 9 per 100	258 2838
18 00	Masonry, brick, plain, foundation, at Rs 20 per 100,	3 6000
69 44	Masonry, brick, arching, at Rs 28 per 100,	19 4432
11,479 49	Excavation in water, at Rs 10 per 1000,	114 7949
	Total,	396 1219

Mill Channel

c ft		
16,8877 08	Excavation in water, at Rs 9 per 1000,	1,519 8937
s ft		
99 00	Gates and planks, at Rs 2,	198 0000
	Total,	1,717 8937

Escape and Mill Channel

c ft		
4,254 40	Masonry, dry boulder, paving, at Rs 10 per 100,	425 4400

Steps

No		
3	Wood-work, at Rs 20 each,	60 0000

Foot Bridges

s ft		
120 00	Wood-work, at Rs 1 8 ...	180 0000

Belts

ft		
291 00	Leather driving, at Rs 3 each,	873 0000
136 00	Leather driving, at Rs 2 each, ...	272 0000
	Total,	1,145 0000

Iron-Work

ft		
219 85	Wrought iron-work, at Rs 28 per maund,	6,156 5000
259 5	Castings, at Rs 20 per maund,	5,182 5000
42 17	Castings, at Rs 17 per maund, ...	728 2250
	Total,	12,060 2250
	Add 10 per cent for erecting, ...	1,206 0225

Machinery from England

			Rs
1	Large saw frame, actual cost at Madhopoor,		7,921 5000
1	Medium saw frame,	,,	6,481 0000
1	Small saw frame,	,,	2,232 5000
1	Set shafting, &c ,	,, ...	3,736 0000
		Total,	20,371 0000
	Add 10 per cent for erecting,		2,037 1000

Tools

8	Large saw frames, No 1, actual cost at Madhopoor, .		99 0000
12	Medium saw frames, No, 2,	,,	138 0000
16	Small saw frames, No 3,	,,	148 0000
4	Circular saw frames,	,,	270 0000
12	Dozen files,	,,	73 0000
		Total,	728 0000

Carriage

259	5	0	Castings from Roorkee to Madhopoor, at Rs 1 8 per maund,	388 6875
521	7	0	Iron work from Madhopoor to site, at 9 as per maund,	293 1609
850	0	0	Machinery and tools from Madhopoor to site, at 9 as per maund, . . .	478 1250
			Total,	1,159 9734
			Add for regulator at the head of the mill channel,	5,073 8059
			Add contingencies at Rs 5 per cent ,	3,169 0000
			Grand Total Rupees, . .	66,512 0000

J D SMITHE

No XXXVII

ALLYGURH FORT

Report on the FORT OF ALLYGURH, *its state and requirements, as a permanent Military Post,* with a European and Native Garrison*

BY MAJOR H WELLER, *Bengal Engineers*

Allygurh, 24th December, 1857

I —PRESENT STATE OF THE FORT

THE Fort, originally of Native construction, was captured in 1803 or 1804 by Lord Lake, by direct assault upon the only entrance gate, in the south face, and not without heavy loss It had then, as now, a broad and deep wet ditch, with an earthen counterscarp, and block kunkur masonry escarp The bastions were high and irregular in shape, and they were subsequently cut down and modernized, though to what extent I am unable to ascertain A ravelin was probably added in front of the entrance gate, and another on the north-east face, with a wet ditch in both cases

Up to 1831 the Fort was kept in good order, up to 1829, by the Head Quarters of the Sappers and Miners, and up to the end of 1831, by a company left for the purpose I personally commanded the last company employed on the works, and marched it up to Delhi in the end of 1831 The Fort was then in excellent order, with numerous substantial pucka buildings, but of the latter all have since been dismantled, except five, which will be described hereafter, and no repairs having been made for about 26 years to the defences, they had of course fallen into a ruinous state prior to the outbreak in May last.

The Fort stands in an open country, about three miles north of the city of Allygurh (or Coel), with its enclosed area somewhat elevated above

the general level Towards the west the country is lower than usual, and there is a masonry inlet to the ditch on that side, which with a little arrangement may be made to drain off any lodgment of water that might otherwise be prejudicial to the health of troops But if the levels do not admit of this during the height of the rains, a drainage cut should be made to the nearest canal escape or rajbuha

The *Counterscarp* of the ditch is a steep and rugged earthen slope, now from 12 to 15 feet above the water level in the ditch It is cut through in many places for cattle walks to the ditch water, and the glacis is very short with occasional low spots at the foot that might afford partial cover for riflemen But the crest of the glacis everywhere covers the whole escarp from external view

The *Escarp* is of block kunkur masonry, and now about 12 feet above the water level, which appears to have fallen about 5 feet, since its highest level in the rains The masonry has fallen down in several places, and in many others is shaken or damaged by the roots of numerous Peepul, and other trees The trees have been recently cut down, but the roots should be more closely cut, and poisoned with a solution of corrosive sublimate

The *Ditch* varies in width from about 300 feet, where greatest, opposite the curtains of the west face, to about 70 feet, where least, at the salient of the ravelin on the south-east It is wet at all seasons, and has a depth at the present time of from $2\frac{1}{2}$ to 9 feet, or more, which however will be particularly ascertained hereafter Measurements all round give 9 feet 6 inches as the greatest depth It must be plentifully fed by springs, and I noticed the water in a well outside on the west face to be only about 12 feet below the surface of the country The ditch has no doubt been much silted up during the last 30 years, by drift, sand, and washings from the ramparts It is shallowest close under the escarp, and if more depth is required there would be no difficulty in obtaining it by dredging

The two *Ravelins* are small in area, with a height of about 8 feet of escarp above the water level, and ramparts about 15 feet above the escarp Their ramparts, as are those of the body of the place, are earthen The south-east ravelin communicates with the body of the place by a masonry causeway of 15 arched openings, about 10 feet 9 inches wide, piers, 3 feet 3 inches thick, and with the country outside,

by seven openings of the same size A drawbridge formerly existed at the inner end of each causeway, but has been since built up solid The north east ravelin has had its exit to the country lately blocked up. *Its communications of eight openings (one pier fallen)* with the country, and twelve openings with the body of the place, were spanned by wooden roadways, which have long ago been removed, and the drawbridges have been built up solid

The body of the place is in shape nearly a square, giving a clear internal area from the foot of the interior slope of the terreplein of about 1,000 feet from north to south, by about 900 feet from east to west It has eight bastions, which I have numbered one to eight, from the flagstaff bastion at the south-west corner, round by west and north There are three bastions in each face, viz, one at each angle and one in each side, not very regularly arranged The three bastions of the north face have been modernized with somewhat regular faces and flanks The others are all more or less circular, and Nos 2, 6, and 8 in the west, east and south faces, are more or less long necked, No 8 being particularly so The terreplein which is of good width has a command of about 13 feet above the inner area of the Fort, with a banquette and rampart of about 7 feet more, and from the general elevation of the Fort above the outer country, which though not remarkable is decided, the ramparts may be said to have an excellent command over the surrounding country, and very fairly to defilade any buildings of moderate elevation that may be constructed within the Fort A berm of 8 or 10 feet width formerly existed all round the foot of the exterior slope of the rampart, between it and the coping of the escarp, and the ramparts may have been about 15 feet thick at top But from the ravages of time and weather, much of the rampart has been washed down on to the berm and into the ditch, so that the thickness at top is reduced to 6 or 8 feet, and all regular shape obliterated The terreplein has been similarly injured, but Lieutenant Watts, Assistant Field Engineer, has during the last two months restored it and the banquette, also the interior slope of the rampart (less completely), and the Fort is even now in a very tenable position against attack with light guns

The bastions are all full except No 4

The ravelins have no berm

Embrasures are now being prepared, and are well advanced towards

completion, partly lined with brick masonry as shown in the sketch on plan, as follows —

	For Guns	For Howitzers
In No 1 Bastion, - - - - - - -	6	2
" 2 " - - - - - - -	4	1
" 3 " - - - - - - -	6	1
" 4 " - - - - - - -	4	0
" 5 " - - - - - - -	4	2
" 6 " - - - - - - -	6	1
" 7 " - - - - - - -	5	1
" 8 " - - - - - - -	6	0
In curtain between 7 and 8, to command road leading to ravelin on south-east, - -	1	0
Totals, - - -	42	8
	50	

and platforms of strong block kunkur masonry are being constructed It would require more mature consideration than I can give to the subject, as my Report must be at once submitted, to decide whether this arrangement of the guns is the best that could be devised But I think it is amply sufficient after the Fort is properly garrisoned and provisioned, to admit of successful defence against serious attack, especially with the help of a few light guns and howitzers for use wherever the attack should be most pressed, and, indeed, considering the noble ditch with its marked escarp, and the general commanding position of the Fort, this Fort may when in proper order be fairly considered a very strong one

The inner area of the Fort is nearly level, rising gently from the sides towards the centre It admits of perfect drainage, which formerly existed by means of open masonry drains round the foot of the interior slope of the terreplein, communicating by arched openings under the ramparts, and through the escarp with the ditch These drains are now being cleared, and they appear in excellent order, together with several masonry reservoirs for water, probably for watering the roads and terreplein They can therefore be restored and made efficient with very little trouble or expense Strong inner and outer gratings should be fitted to the exit drains

The only buildings remaining in the fort when the outbreak occurred, were—

A pucka vaulted guard-room of two rooms, near the entrance in the south face This is much dilapidated, but with repairs and the addition of doors and tiled verandahs, it may be put into good order

A pucka vaulted house near the above, probably used as a main guard or for officers' quarters This consists of two good sized rooms with verandah rooms all round, and it is in excellent order, doors only excepted, and Lieutenant Watts has already supplied choukuts for them

A pucka vaulted cook-room and privy, in fair repairable order are in rear (west) of the above

A pucka vaulted magazine with masonry enclosing wall round it This is in good order, massive and of excellent masonry I doubt not therefore it will be found bomb proof, and with the addition of double doors, and opening out ventilation in the side walls, it will prove an excellent magazine for all the powder required It stands close under the rampart near the north end of west face, and is now divided by a temporary wall into two compartments, occupied for magazine and commissariat purposes

Near the rampart on the north face, a rather dilapidated pucka flat roofed building, now used by the commissariat The roof had fallen in, beams only remaining, and Lieutenant Watts has given a temporary mud roof This building is repairable, and if it does not interfere with other more important arrangements, may be found useful as a store room for European troops

A pucka vaulted range in No 4 bastion, now used as a bakery This was in much disrepair, but has been partially repaired by Lieutenant Watts, and may I think be rendered serviceable if desired It is not badly situated for a bakery, but probably the bakery and commissariat cattle, and slaughter-yard, may with advantage be removed to the ravelin on the north east side, in which case this building or its site will be useful for some other purpose

Wells There are nine wells in the fort, and the water in all is said to be very good , the depth of water varies from 2 to $15\frac{1}{2}$ feet, at a distance below the surface of from $18\frac{1}{2}$ to $34\frac{1}{2}$ feet, and with proper clearing out these wells will afford an ample supply of water for all purposes

There are no roads now in the Fort, but kunkur is plentiful in the vicinity, and when the arrangement of the buildings is decided on, the

Fort roads can easily be laid out and constructed The metalled road also from the city of Allyghur should be repaired, and a direct line opened to the Grand Trunk Road leading to Delhi and Meerut

It only remains, in connection with the present state of the Fort, to mention the works and temporary buildings completed or in progress by Lieutenant Watts since the 22nd October, 1857

The interior of the Fort has been cleaned up

The interior slopes of ramparts (partly) and the banquette, terre-plein and ramps, with a portion of the ramparts, have been substantially repaired with rammed earth

Old buildings have been partly cleaned and repaired, with some doors, choukuts and gates supplied

Wells have been partly cleaned out

Embrasures have been opened out in the bastions, and gun platforms of block kunkur masonry commenced upon

Mounds outside the Fort have been levelled

A temporary staging bungalow, thatched, with sirkee and grass tattie walls, of two rooms, has been constructed for the accommodation of travellers

The metalled road leading from the city of Allyghur is being repaired

55,000 large bricks, and 20 lakhs of small bricks, with 5 lakhs of small tiles, have been collected , and arrangements made for bringing in 2,000 cubic feet of block kunkur, and 500 maunds of kunkur lime, daily

Five temporary barracks, and a hospital for European troops, also a range of officers' quarters, have been completed Masonry, kutcha pucka Roofs, of light thatch

Six ranges of barracks for Seikh troops are well advanced towards completion, and will be ready in a few days They are of kutcha masonry , the roofs are of small tiles , and with the addition of quarters for native officers at the west end, and a cooking shed at the east end of each range, I think these barracks will afford good accommodation for 300 Seikhs A seventh range is sanctioned, but has not yet been commenced It will be useful as an hospital for the Seikhs, if a native garrison is decided on, but upon this subject I beg to refer to the annexed Memo by Colonel A Becher, Quarter Master General of the Army, and myself

II REQUIREMENTS OF THE FORT, AS A PERMANENT MILITARY POST WITH A EUROPEAN AND NATIVE GARRISON

To place the Fort in a proper state of defence the following work appears necessary —

Exteriorly, the demolition of two villages, about three-fourths of a mile from the west face

Slight levelling of inequalities for a distance of at least 800 yards all round the crest of the glacis

Filling in a little at the foot of the glacis, where some slight hollows might afford partial cover to riflemen

And a careful repairing of the counterscarp which at present is much furrowed by rain water, and in many places cut through for cattle runs to the water of the ditch The counterscarp should also be planted with *doob* grass next rain

Further, as a sanatory measure, and to avoid giving cover to an enemy, no cultivation should be permitted within a radius of one mile all round the crest of the glacis

The wet ditch has at present a depth of water varying from 2½ to 10 feet It is shallowest near the escarp, and may hereafter with advantage be deepened by dredging

Interiorly, the escarp masonry will require extensive repairs, with careful removal of the roots of trees, which have occasioned much damage

The wooden roadways of bridges over main and ravelin ditches on north east side, should be renewed Also drawbridges furnished at the inner ends of these bridges, and of the masonry bridges at the main entrance on south face Substantial gates will also be required

The earthen ramparts all round should be restored to a proper profile, and the whole carefully turfed during next rainy season The soil is very stiff, and if once well repaired and turfed, I think only very trifling repairs can be wanted for many years

It will be necessary to close the outer berm on either side of the entrance and exit gateways by a strong palisade, to prevent surprise of the gates by any party who might cross the ditch unobserved.

H WELLER, MAJOR

Memorandum by COLONEL A BECHER, *Quarter-Master General of the Army*

Allygurh, 24th December, 1857

It is considered that for permanent barracks for European infantry or artillery, the main ward should be 24 feet wide and 24 feet high, 8 feet of space is required for every two cots, that is, for a company of 100 men, 50 cots are required down each side of the main ward

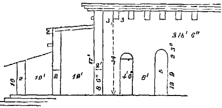
Say therefore for one side—

	Feet	Inches
2 end spaces for 1 cot each, at 4 feet, - - - - -	8	0
24 spaces for 2 cots, each at 8 feet, - - - - -	192	0
25 arched openings at 4½ feet, - - - - - -	112	6
Add for 3 cross walls of 2 feet each, to strengthen the side walls and divide the barrack into 4 spaces each, for the section of a company, - - - - - - - -	6	0
Gives total length of main ward inside, - -	318	6
Add 2 walls of 2 feet each, - - - - - -	4	0
1 set of Sergeants' quarters (2 rooms) each 16 feet long by 10 feet wide, with 5 feet passage leading into barrack, -	16	0
Partition wall 2 feet, another set of Sergeants' quarters, 16 feet, - - - - - - - - - - -	18	0
Outer wall 2 feet, inner verandah 12 feet, its outer wall 1½ feet, - - - - - - - - - - -	15	6
Outer verandah 10 feet, its pillars 2 feet, - - -	12	0
Gives total length of a barrack, outer dimensions, -	384	0

And for the breadth—

	Feet	Inches
Main ward 24 feet, 2 walls 4 feet, 2 inner wards 24 feet, their walls 4 feet, - - - - - - - - -	80	0

Each barrack will therefore occupy 384 feet by 80 feet, inner wall 24



feet under beams, inner verandahs 17 feet under beams, outer verandah 10 feet under beams, plinth to be 3 feet high in 4 steps of 9 inches high each, all round

The arched openings in main ward to be 15 feet high and 4½ wide Doors in outer wall of inner verandah to be 8½ feet high by 4½ feet wide, every third door half glazed, the others panelled, and all with semi circular fanlights over them, pivoted in the centre to open or shut at pleasure

Three of these barracks to be constructed in the Fort of Allygurh to accommodate 200 infantry and 100 artillery, and if hereafter it is desired to increase the garrison, upper stories can be added, though perhaps if this is contemplated the main walls should be increased to 2½ feet thickness Masonry to be all pucka of block kunkur slabs and lime mortar, arch work only excepted, which will be of brick and lime Double arches segmental and semi-circular (unless the fanlights are made rectangular, in which case the arches may be flat and semi-circular) over the doorways, and *invert* arches *in foundations* under doors in inner verandahs, and arched openings in main ward Roofs to be flat, lime terraced, with three skylights if deemed expedient Floors to be of slab stones from Agra

All requisite subsidiary buildings to be provided Also hospital accommodation for 50 men, or the size of half a barrack, which is about 16 per cent on a strength of 300 Europeans

Quarters for the Fort Commandant and Garrison Engineer, and Adjutant, also for Regimental Officers, to be provided upon a scale that has been approved of at Head Quarters, and will be hereafter furnished These quarters should be pucka and flat roofed

For a native garrison, if eventually decided upon, six ranges of barracks with mud brick walls and tiled roofs, now nearly finished, will accommodate 300 men, but quarters for native officers should be added at the west end, and a cooking room at the east end, which is near the ramparts

Commissariat accommodation can be provided under the terreplein in pucka vaulted buildings, as many as are found necessary, so too for gun-sheds and all artillery requirements, except the magazine For the latter purpose the present magazine will, it is believed, prove ample and safe

The commissariat cattle and slaughter-yard may be in the north-east ravelin, and as guns are not required there (so near to the body of the place) the terreplein can be cut away 15 or 20 feet and afford extra space

Communication with the outer country should be restored through the north-east ravelin, as filth carts and commissariat offal can then be

properly taken out and deposited in a field not less than three-quarters of a mile to the north, without inconvenience to the garrison

Accomodation will be required for some horses (how many is doubtful) and can be afforded by revetting the lower 5 feet in height of exterior slope of rampart with block kunkur, and giving a wall 5 feet high along the coping of the escarp to such distance east and west of the gateway leading to north-east ravelin as may be desired Or a small earthern *tete de pont*, with musketry profile, can be thrown up in front of the north-east ravelin bridge leading to open country, and in this the horses could be kept

Regarding the strength of the garrison, (limited in Major Weller's instructions to 250 Europeans, with such proportion of natives as may be deemed necessary,) it appears desirable that at least two full companies of European infantry should be located in the Fort The artillery should properly be equal to manning the guns of one complete face, or what is the same in essentials, the guns of one angle bastion and of the curtain bastions right and left of it Provision is being made for embrasures for 50 heavy guns and howitzers, which against serious attack can hardly be deemed an excessive armament This would give, say, 17 guns on the face attacked, exclusive of a few light guns and howitzers, to be used as required Then 17 guns $\times$ 8 per crew = 136 gunners, or for three reliefs, 408 gunners Allowing therefore for assistance from the European infantry in working the guns, provision for 100 artillerymen is the lowest strength that can be given in this arm, if indeed it is not, as seems probable, very inadequate The minimum European garrison is therefore assumed at 200 infantry and 100 artillery For the native garrison 300 men would be a fair and useful proportion, if the limited area of the Fort did not render it very difficult to provide adequate shelter for natives

But with advertence to this difficulty, which is almost insuperable, unless the natives could be located in pucka vaulted quarters constructed under the terreplein, (against which the excessive heat of such quarters in the hot weather is the only objection,*) it appears worthy of consideration whether native troops should not be located outside the Fort, south or south-west, and a guard room for 100 men provided inside This guard would be sufficient for all Fort duties in time of peace, and in event of attack there would be no hardship in placing the remainder of the native

* Such underground quarters (tackhanas) are common in large native forts and are very cool —[ED]

garrison in tents for the short time that would probably elapse before the place was relieved, or the quarters under the ramparts could be prepared, though only occupied in case of siege

It is also worth consideration whether Allygurh will not be made a cantonment for at least one European and one native regiment with artillery If so, it might be located about one mile south or south-west of the Fort, and furnish a sufficient guard for the Fort duties in time of peace

Adverting to the limited area of the Fort, and the difficulty of providing sites for even three European barracks and a hospital, (besides which officers' quarters, and numerous minor buildings are indispensable,) the accompanying plan shows what is considered the best and most convenient sites for the main buildings It will be observed that very little available space is left, and consequently though upper-storied barracks will be exposed to view from the outer country for probably the whole upper stories, yet this arrangement seems most expedient And, if approved of, it would leave sufficient space for all other requisite buildings The rampart might also be raised two or three feet, which would better defilade the upper stories though not completely

A. BECHER, COLONEL.

No XXXVIII

SILT TRAPS ON THE DEHRA DOON CANALS

By R E FORREST ESQ, *late Superintendent Doon Canals*

AN old Italian writer on irrigation expatiates on the great advantages it would have been to canals, had "nature only provided that the rivers from which they are derived should always run bright and clear, and that their waters should never be intermixed with foreign substances!" Silt and sand are indeed the great enemies of all irrigation canals They block up the entrance to their mouths, or raise the bed and necessitate embankments, or shut up the openings of the smaller irrigation channels, and their baneful influence is felt in many other ways They form a component part of the economy of all great rivers, and in large canals, which are often in size merely regulated rivers, there seems to be no way of excluding or getting rid of the foe, or at all events of doing so at all effectually

As might have been expected, this subject has largely engaged the attention of the Italian Engineers Some of their most interesting writings treat of the depositions of Silts and Gravels, and of their efforts to exclude or get rid of the latter, with which they had chiefly to deal

* "Some authors have proposed expedients to prevent any sort of gravels from entering canals Eustace Manfredi, in treating of the means of drawing from the Lebir a fixed branch from below Porto Nuovo to below Perugia, proposed the construction of a weir, which in consequence raised the surface of the water eight Roman palms He directed also that the sill of the entrance at the head of the canal should

* These extracts are from Paul Frisi's book on "Rivers and Torrents," translated by General Garstin

be five Roman palms below the heightened surface of the water, so as to retain in the canal the sufficient depth of five palms of water, and by the three redundant palms to prevent the introduction of any pebbles

"Again, Belidor, in the sixth chapter of his book, above quoted, has suggested the idea of receiving the waters into a great reservoir in which they might deposit their gravels before they entered the canal, but although this plan has been practised in the famous canal of Languedoc, it is always liable to the objection that it is extremely difficult and expensive in the execution, and never applicable to any case in which it is necessary to draw a fixed channel from a great river running between mountains"

The above was for *excluding* gravels, and to *remove* them —"They have sufficiently provided for the clearing out of the beds in the upper trunks of these two canals, where stones and gravels are brought down in great abundance with the stream, by placing in them a number of dischargers sufficient for the purpose, called bottom or ground sluices This sort of outlet should be constructed in the bank of the canal on the side nearest the river, in such a manner that their sills may be lower than the bottom of the canal itself The waters that are occasionally suffered to precipitate themselves into the river from such apertures acquire great velocity * * * * * As this acceleration extends a considerable way from the opening of the grooves, substances are detached from the bottom * * * With several sluices of this kind, which are opened at proper times and which are so distributed that at the spot where the action of one ceases, the action of another begins, the gravels which had entered the canals are forced to throw themselves again into the river in the least space of time possible"

The large irrigation works in these provinces suffer from the more subtle and more annoying, if not more dangerous, of the two enemies, viz, Silt And no steps have been taken to exclude or get rid of it on the large canals in the plains, as none seem possible owing to their great size and the large volumes of water they carry. But on the smaller water-courses in the Dehra Doon, measures have been carried out to intercept and remove the silt, and while the smallness of these water-courses allowed of this being done, it was a matter of absolute necessity in their case that it *should* be done as will be seen further on. One

thing that made it necessary was, that they supply water not only for irrigation but for domestic use And as this may one day make it necessary even to purify the water of larger streams, if used for this latter purpose in India as in England, it may be as well to say a few words with regard to the several methods of purifying water A mention of the principles on which the action of the Silt Traps depend will be of use before proceeding to describe their construction

The means by which water may be freed from its impurities are either 1st, Chemical, or 2nd, Mechanical With the former we have nothing just now to do, Mechanical means are the only ones as yet employed in the Doon Silt Traps All the methods of the second, or Mechanical clearing of water, are one or the other of two processes, viz, Subsidence and Filtration "The first of these processes is of a negative character, consisting simply in letting the water remain for a considerable period in an undisturbed condition It is well known that if a quantity of water having particles of any foreign matters of greater specific gravity than itself floating or diffused in it, be allowed to continue in a quiescent state for a sufficient length of time, these particles will subside to the bottom of the water which is thus left comparatively clear and limpid

"The process of Filtration is effected by providing a bed of easily procurable materials, in which the water deposits the solid particles which it held in suspension, and finds its way to the lower bed in a comparatively clear state"

Both these principles have been brought to bear from the earliest times The Romans had their Limaria and Conceptacula The former were open air reservoirs or cisterns, the latter reservoirs vaulted over to shelter the water from the influence of the atmosphere In the Limaria, the principle of subsidence was employed, and the stillness in the water requisite for it was obtained not merely by increased width and depth but also by change of direction Thus (*Fig* 1) the water flowed into the Limaria at the point A, and its exit was at B, or at right angles to its original direction, which it regained by another turn Filtration was performed in many ways, principally by taking advantage of the height to which the water was brought before it was made use of, by building one reservoir over another, and letting the water from the upper one flow into the lower.

Both these principles are also employed in the arrangements made for purifying the water intended for the supply of towns in England I need not refer to those for filtering yet Of the arrangements for the preliminary or settling process, I copy the following description of that employed by the Southwark Water Company, which bears most analogy to the method employed in the Doon

"The system of cleansing adopted by the Southwark Water Company embraces settling reservoirs as well as filtering beds or reservoirs, and some peculiarities in the formation of the former deserve notice The section (*Fig* 2) will clearly show the construction A, A, are the settling reservoirs, having an area of between four and five acres, and being 13 feet 6 inches deep, and faced with gravel The beds are formed with a slight inclination from the sides towards the middle, along which an inverted arch, *b*, is formed of brick-work in cement, 6 feet wide and 3 feet 6 inches deep This invert is an essential improvement, and with the inclined bed gives great facilities for cleansing by sweeping the deposits into the invert and flushing it away with a current of water from an upper reservoir "

By this method the deposits are removed at once from the settling beds without these being kept out of use, which would be the case had the deposits to be removed by manual labor But they are not thus got rid of once for all In fact, as the clear water after passing through the filtering reservoir has to be raised to the surface by means of a pump, it would appear that the deposits were only removed by the above means from the settling reservoir, which has to be kept in constant use, to some side pit or reservoir, from which they could be removed at leisure

In Switzerland a construction is employed which combines the actions of Settlement and Filtering A long rectangular reservoir is divided into a series of small square reservoirs by means of parallel cross walls (See *Fig* 3) The water flows over the top and through an opening at the foot of each alternate one of these walls *Fig* 3 shows the mode of action at once, the water proceeding in the direction of the arrows It is evident that this apparatus can be made to filter the water also if required But here too there are no means shown by which it may be rendered self cleansing

The mere *impurities* ordinarily carried by water bear but a small pro-

SILT TRAPS

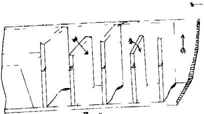


Fig 3

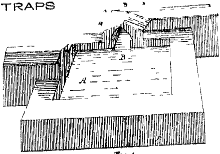


Fig 1

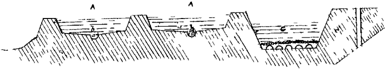


Fig 2

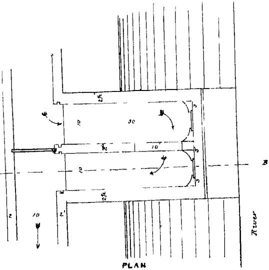
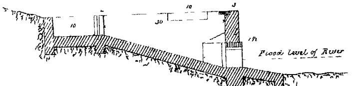


Fig 5

PLAN



Section on A B

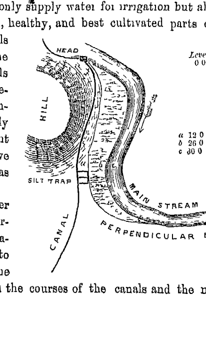
portion to the volume of the water itself The accumulated sediment would form no great mass during a long space of time, and the above contrivances are adapted for this state of things But other arrangements were necessary on the Doon Canals where large sized gravel had to be got rid of, and where, during the floods in the rains, the water-courses ran with silt and water in almost equal quantities

The water courses in the Doon are taken off from the different hill torrents which flow down from the Himalayas, and which all flow over boulder and gravel beds Owing to the great velocity of these mountain streams, due to the steep slope of their beds, they are always more or less charged with silt " Even during the winter months, when the water in these small canals appears to be flowing along in crystal clearness, a slight stoppage at any point will at once produce a deposit of a coarse blue sand " In the rains, when the hill torrents come down in floods, the gravel of their beds begins to move, heavy masses of shale and gravel are brought down from the landslips which they cause, as they impinge on the sides of the hills which bound their course, and the streams become nothing but moving lines of silt and water, and thus enter the different water courses of the country

In the Canals of the plains the silt is a sufficiently great evil But the evils are chiefly that it entails great trouble and expense in removing it It may prevent some improvements (as for instance the introduction of the module) from being carried out, but it does not do any positive damage It is, however, otherwise on the water courses in the Doon These water-courses are almost of masonry The slope of the country is so great that an earthen channel, which cannot in itself have a steep slope, would have to be provided with so large a number of falls that the expense would not be far below that of a masonry channel, to which a very rapid slope can be given, and which can thus carry water with a much less section, besides having a smaller number of falls Besides this, every drop of water in the Doon is valuable, and a masonry channel prevents all loss from absorption Thus the Doon water courses may be described as long masonry conduits, having a section of from 5 × 2 feet to 10 × 4 feet, with a slope of bed of from 50 to 80 feet per mile, and still having numerous masonry falls, 5 and 6 feet in depth, on them They also generally pass over numerous and long aqueducts To these water-courses therefore the presence of silt

causes immediate and absolute damage The water rushes down these channels with tremendous velocity, and the gravels carried by it tend to injure all the masonry works over which they pass by the force of impact, while the silt acts even more injuriously, cutting into them with an action like that of emery powder Even to a bed laid with large boulders great damage is caused, the mortar joints are washed out, the boulders lifted out of their places, and then rolled along the bed to add to the mischief But it is to brick work that the greatest injury is done In fact it requires but time to make all brick-work disappear entirely in the presence of such action In some of the old canals there was a flooring of brick-on edge over the arches of the aqueduct On one of these aqueducts I have seen not only the foot in depth of the brick floor entirely cut through, but deep ruts formed in the arch itself But it was on the falls, which were all formerly built after the ogee pattern and of brick, that the damage was greatest as might be expected Their surfaces were cut into deep striæ, and they were in constant need of repairs, which were difficult to execute

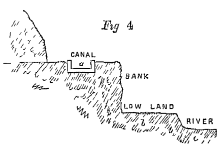
It was therefore important as a matter of mere canal conservancy to keep the silt out But it was also necessary for the sake of the people, as these water-courses not only supply water for irrigation but also for domestic use In the high, healthy, and best cultivated parts of the valley, the water in the wells is 180 and 200 feet from the surface of the ground Wells are therefore practically useless The people are dependent for their water supply entirely on the canals, and it is therefore necessary to have the water in them as pure as possible



Thus, it was very soon after the construction of the water-course themselves, that measures began to be taken to intercept and get rid of the silt. The relation between the courses of the canals and the natural

features of the country afforded an easy method of doing this. Taken off from various hill torrents they rapidly rise above the bed of the parent stream, and for some distance from the head, and before they run on to the table lands they are meant to irrigate, they have to run along the side of the hill or high bank at the foot of which the present stream runs. It is evident how the drop and hollow space between the canal and the river afford an opportunity for the construction of a reservoir such as we need. *Fig.* 4 will convey an idea of this state of things. It is in fact almost an exact representation of things as they exist on the Kalunga Canal.

Fig. 4



Section along a b c (To no scale.)

It is evident that a reservoir or Silt Trap can be built at the point *a*, through which the water of the canal being made to pass, it will deposit its silt and gravel in it.

The first Silt Traps built in the Doon were of the form shown in *Fig.* 5. The mode of action, and the application of the principle of subsidence are at once evident. The water is diverted from its straight course into the first chamber of the reservoir, pours through a slit in the top of the dividing wall into the next chamber, and from there returns again into the canal. The silt settles down into the deep and comparatively still water of the chambers. By giving the beds of the chambers a slope towards the end wall, and having openings at its foot, the silt was got rid of at once solely by the action of the canal water.

These Silt Traps were built on the Kutta Puthur Canal and the Rajpore water-course. Similar errors of construction attached to both of them, which caused them to be of little service. But there was an error of position in the latter which soon led to its total abandonment. The Kutta Puthur Canal Silt Trap opened on to the Jumna river, and its silt evacuations were thus speedily got rid of. But that on the Rajpore Canal was connected with the natural stream by means of a long and tortuous channel. The consequence was that heavy silt deposits took place in this channel. A mound of silt was formed at the foot of the

Silt Trap, advanced on it year by year, and finally rested against the end wall to its top, and the Silt Trap had to be abandoned It had in fact got buried in silt It is a point never to be lost sight of that a Silt Trap ought to open immediately on to some natural stream It ought never to be attemped to carry away the silt by means of flushes from the silt trap itself and along an artificial channel If possible, the high water of the natural stream ought always to come up to the foot of the silt trap wall

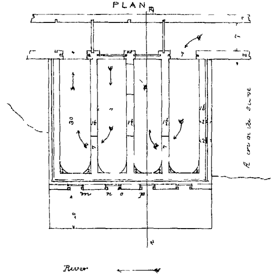
The errors of construction in these first Silt Traps were—1 That the dimensions of the canal were carried through each part of the Silt Trap, the width of the chambers and of the opening in the dividing wall being made the same as the width of the Canal The consequence was that the water flowed through the trap with a considerable velocity, and thus carried on a great quantity of silt 2 That the gates for the openings at the ends of the foot wall were large and clumsy There was a great loss of water through them, and being 4 feet square, they were difficult to lift, more especially when the silt deposit quite covered them, it was then like trying to pull up a pile out of sand

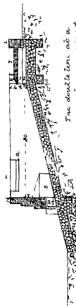
The next Silt Trap built was that on the Kalunga Canal in which these defects were remedied Here, (*Fig* 6,) a double set of chambers was employed Greater stillness was obtained by having these additional reservoirs and also by placing the openings in the separating walls at alternate ends, by which means the water had three turns in its course through the trap And with a double set of chambers, one set could be kept in action while the other was being cleaned out Two different kinds of gate were employed For the openings in one set of chambers they consisted merely of small rectangular plates of iron, $1\frac{1}{2}$ feet deep by 1 foot broad, which rested against the sides of square beams previously let into the wall They were held against the opening, and moved under two thin strips of sheet iron attached to the wooden beams, and which covered their edges for $1\frac{1}{2}$ inches (*Fig* 7) These plates were inside the reservoirs and the pressure of the water made them almost perfectly water-tight They were moved up and down by means of a long iron rod attached to them, and which reached to the top of the end wall The upper foot and a half of its length was cut into a screw As the shutters could not descend by their own weight owing to the spring like pressure on them of the strips of iron, it was necessary that

SILT TRAPS

Fig 6

PLAN





The double line at a shows the rounding of the top of the wall

Section on AB

Fig 8

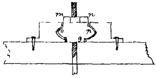
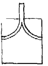
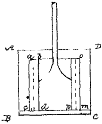


Fig 7



m n o n q forms one pc and contains the female screw It is in fact a large nut

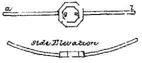
Iron Shutter



Iron Shutter

A B C D Corners of Wood work seen against wall a d o p sheet iron strips fixed to wooden beams and acting like springs Dotted lines edges of iron shutter under strips which hold shutter down

Plan



Side Elevation

Lever for turning fixed nut m n o p q

The hollow socket qv fits over m n

the rods should push them down as well as pull them up, in fact that the screw should act both ways This was effected by the arrangement shown in *Fig* 8 The double handled lever, *ab*, has an octagonal socket in the middle of its length This fits over the octagonal nut, *mn* When the lever is worked to the left, the gate is pushed down, when, to the right, the gate is lifted up

This is undoubtedly the best form of gate that can be adopted There is no leakage through it, and the screw affords the most perfect mechanical agent for working it But its very perfection was one objection to it, it was too good for the locality If any thing happened to the screws there was no means of having it remedied within a distance of fifty or sixty miles Again, while admirably adapted for a regulating gate it could not be used as a flood gate And this last was absolutely needed, for when the chambers rapidly filled up with silt there was danger of the water flowing over the walls of the Silt Trap Another form of gate was therefore employed in the other two chambers The principle of their construction is extremely simple, and they can be made up by any village carpenter Their mode of action can be easily understood from the diagrams The gates open outwards so that the force which opens them is the pressure of the water The bar, *ab*, which keeps down the gates (*Fig* 9), runs into two openings made in the side beams *cd*, *ef*, (which project a good deal beyond the surface of the gate,) and its ends fix into two sockets, one of which runs upwards and the other downwards The gate, as shown in *Fig* 9, is closed If the end A be struck from above it will descend, while the end C will ascend till both ends come opposite the openings *m*, *n*, in the side posts, through which they fly out and the gate flies open from the pressure of the water within. It will be observed that the pivot *p*, on which the bar turns is placed so as to give the advantage of the leverage to the descending stroke It will be observed also that the end of the bar being octagonal, it is only the pressure on the length of one side of the octagon which has to be overcome Hence the gate is thrown open with the greatest facility One man can strike open three gates, with a pressure of 14 feet in depth of water on them, with the greatest ease

The bar may be struck from the top of the end wall with a pole, or from the tops of the small projections, *mn*, *op*, (*Fig* 6,) built on each side of the gates I do not know if this form of gate has been employed

elsewhere It seems to me that it might with great advantage be employed in the flood gates for dams and weirs The fact of the gates swinging from above would militate against its employment in the centre of a dam or weir across a river subject to heavy floods. But from the extreme rapidity with which they can be struck open, they would be of great service for side sluices meant to relieve the first rush of water in floods The simplicity and cheapness of their construction (no iron work at all being employed in them) render them suitable for the wild and uninhabited districts in which the heads of canals are generally situated *

While the Silt Traps first built were of little service or had to be abandoned altogether, the Kalunga Canal Silt Trap has done good service for the past six years The use of the double chambers becomes at once apparent on examining the quality of the deposits in each chamber In the first two, is chiefly coarse heavy gravel, in the third, coarse silt, in the fourth, fine silt The last was never deposited in the old Silt Traps, but was carried on into the Canal

There were still, however, many faults in this form of Silt Trap The dimensions of the canal being still carried through the trap, the velocity was very great, perfect stillness had not been obtained It was obviously a mistake that the last opening out of the trap should be of the same size as the first opening into it It was an error in Engineering to have so great a length of fall at the end wall, standing *en l'air*, while exposed to the full pressure of the water From these considerations it became evident that an improved form of Silt Trap ought to have — 1. The opening for the exit of the water as wide as possible 2 The openings for communication at the foot of the dividing walls of the chambers 3 The end wall as short as possible These principles were accordingly carried out in the Silt Trap last built, viz, that on the Rajpore Canal It will be observed that the water passes out of the trap (*Fig* 10) over a long weir The length of this was calculated so that it should have only 3 inches in depth of water passing over it in the rains, and not more than 1 inch or $1\frac{1}{2}$ inches at other seasons Thus ordinarily, merely the surface water passed over it, and the water was cleaned

* This form of gate was devised by Lieut Edmund Walker, of the Bengal Engineers, when Superintendent of the Canals in the Doon, to whom also most of the improvements in the construction of the Silt Traps are due By his death, which took place before Delhi in July, 1857, the Indian Government lost one of its promising officers, and his friends sustained a loss which they have not yet ceased to mourn

SILT TRAPS

Fig 9

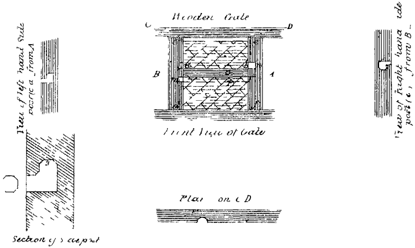
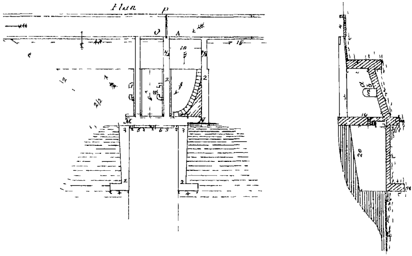


Fig 10



of leaves, straw, and other substances, as well as of silt The water was almost purified The openings of communication, *ab*, are at the foot of the dividing walls of the chambers The water thus passed on by means of pressure alone, there was no surface velocity The water in the first two chambers was almost dead still The end wall, MN, of the trap was made as short as possible It was strongly supported by the side wall of the escape channel, and all danger of accidents was thus removed

Other minor improvements were carried out in the construction of this trap It had been found to be very difficult for a man to walk down the steep slippery floor of the Silt Trap to the gates, which it was often necessary to do Steps were therefore made in one of the angles of the first chamber of the new Trap and a small flat cut along the floor and through the openings along which a man could walk Advantage was taken of the side walls of the escape channel to throw a wooden platform across immediately over the gates (not shown in plans). Holes being cut into this immediately over the end of the bars of the gates, poles were kept ready slung through them so that the bars could be struck and the gates thrown open at any moment

After the Silt Trap was built it was found that the action of a principle in hydraulics had been overlooked The length of the dam had been calculated strictly so as to allow of the passage of the greatest supply of water over it at a certain depth The tops of the side walls were fixed with regard only to this and the depth of water in the canal The velocity of communication through the chambers was overlooked, and the heaping up of the water in the first two chambers was so great owing to this that the walls had to be raised to meet it The different degrees of level at which the water stood in the three chambers was distinctly marked to the eye Measurements of this would be interesting and useful

The still water in the first chamber of the Silt Trap acts as a dam to the water in the canal If possible there ought always to be a fall in the canal immediately above the Silt Trap

Should it become necessary, actually to purify the water by means of filtration, as may yet be the case for the supply of the rising town of Dehra, an apparatus for the purpose could easily be adapted to the Silt Trap The dividing walls might have cisterns at their feet (sunk below

the level of the flooring) which they would span by means of arches Those cisterns would be filled with gravel, sand and animal charcoal, and covered with perforated zinc plates, to prevent these materials from being washed up The water would be forced to pass through the cisterns and would be completely purified

The operation of filtration would however be slow and the Silt Trap would have to be enlarged to meet this In fact, filtering traps would be best kept apart from the irrigation works of the canal in which rapidity of discharge is the great point sought There ought to be a separate construction for it

No XXXIX

ALLAHABAD SPECIFICATIONS.

[The following extracts are taken from a very useful book of Specifications, Rates, Contracts, &c, prepared for use in the 2nd Circle, N W. Provinces, by Capt F W Peile, R E, Superintending Engineer Other specifications will be published hereafter]

Roads

Maintenance of road —The surface of metal, whatever its width, to be always kept free from holes, ruts, and worn-patches, and to be maintained as much as possible with its due central rise of 1 inch per 3 feet transversely, and to its full original width

Immediately on the appearance of any failure of the surface such petty repair shall be executed as shall restore the portion to its original condition

The repairs shall be commenced always within 36 hours of the first appearance of failure

In executing such petty repair of metal, the hole, or rut, or patch, shall be cut out to the full depth of the coat of metal in a rectangular form, enclosing the whole of the patch and parallel with the centre of the road, the sides of the excavation shall be sloped off

Metal of the quality and description specified for annual repairs shall be laid into the hole and properly consolidated, the surface of the new patch when completed, lying perfectly even with the remainder of the road

The metal for these petty repairs shall be supplied by the Contractor, and he shall be bound to keep up a constant supply of 1,000 cubic feet

in each mile of road, to be stored separately from the annual repair metal in such convenient depôts as he may choose for each mile.

The earthen sides and slopes of the road shall be kept even, free from ruts and holes, and generally ranging in height with the surface of the metal.

The side drains and water channels shall be kept open and free for the discharge of water.

The surface of the road generally shall be kept free from accumulations of water.

The road side trees are to be tended and cared for, the lower branches of large trees to be lopped carefully during the months of December and January to the requisite height, to admit a free head way for the traffic, and no more, but without injuring the trees. All limbs of trees are to be *sawn off*. Young trees to be protected from injury by traffic or cattle in the usual manner with thorns or mud walls, where necessary.

Collection of metal for repairs.—The *kunkur* to be hard, clean, and fit for road metal in every respect, broken to 2-inch guage, to be sieved and cleaned, so as to be perfectly free from earth and other matters before it is brought to the road side.

The *moorum* to be hard and firm, so as not to be easily crushed under the foot, to be of a sharp gravelly nature, and free of soil; to be sieved at the quarry, meshes of sieve not less than $\frac{3}{16}$ of an inch square.

The *stone* to be of hard close texture, (not friable sand stones), to be broken to a size to pass through a $3\frac{1}{2}$-inch ring every way for the lower layer, and $1\frac{1}{2}$-inch ring for the upper layer, no round or pebble-shaped stones to be allowed amongst the metal. The stones to be broken clear of the road and slopes, and must be perfectly free of earth or other matters.

The metal to be stacked on the berm, free from the sides and slopes and side drains. No metal to be measured until it has been so stacked.

In measuring the metal collection, the product of the length, breadth, and of $\frac{12}{13}$ of the height, will always be held to be the net cubic contents of the stack.

The metal collection for annual repairs is all to be effected between the 1st November and the 30th April next ensuing.

Consolidation of metal for repairs—The surface of the old metal is to be scored up with the pick in parallel diagonal lines at 6 inches intervals

Two parallel mud walls 8 × 6 inches to be formed along the outer edges of the metalling, leaving an interval between them of the full width of the metal, to confine the metal and prevent its spreading under the action of the rammer

The new metal to be spread upon the old surface closely packed with the hand, the larger pieces below and the smaller above

The surface of the new metal to be laid with the usual central rise of 1-inch per 3 feet transversely As a guide to the workmen $5\frac{1}{2}$-inch cubes of wood will be laid at intervals of 16 feet along the centre, and 3-inch cubes along the side of the metalling, the upper surface of which after consolidation must coincide with the tops of the cubes Care must be taken to bed all the cubes on one horizontal plane

The metal to be saturated with water and rammed with rammers until thoroughly consolidated, that is, until the wheels of ordinary light vehicles passing over it cease to leave any impression The surface to be watered for three days after this consolidation has been effected

Earthwork for repairs of sides and slopes—The earthen sides and slopes receive periodical repairs simultaneously with the renewal of the coat of metal All other repairs to them will fall under the head of maintenance

The repairs consist of making up the sides to a width of 8 feet from the edges of the metal coat and to the full height thereof, with a slight fall to the outside to throw off water, and in filling in all holes and channels in the slopes, and dressing them off evenly

The earthen sides and slopes are to be repaired immediately after the adjacent portion of metal has been opened for traffic The clods will be broken down, the surface rammed and smoothly dressed

Excavations for supply of the necessary earth will in no case be opened within 36 feet of the centre of the road The Executive Engineer will give special directions in this matter where necessary

Earthwork—To include all embankments raised and excavations cut—tanks, hollows, or channels filled, or excavated in any gravel or clay soils, but to exclude excavation for foundations and wells

One foot vertical lift to be taken as equal to 10 feet horizontal lead.

In the case of an embankment, this proportion for lift to be added to the horizontal lead.

In filling an excavation or hollow, the horizontal lead only to be allowed.

The lead to be measured in the case of a road, from the centre of the excavation to the centre of the bank.

In filling a hollow or excavation, from the centre of the cutting to centre of hollow.

In case of tank cutting, &c., from its centre to centre of spoil bank.

If the soil has to be carted, the excavation will be paid for under that head without lead, and the cartage separately at the Schedule rate for that work.

Earthwork shall be measured from sections of the bank to be raised, or hollow or excavation to be filled, or bank or channel to be cut. In the first and third cases, cross sections shall be taken at no greater intervals than 330 feet, and each portion between two sections shall be calculated separately as a pyramidal frustum or from published tables.

In the second case, the hollow or excavation shall be measured before the work is commenced, and the Executive Engineer and Contractor shall agree in writing as to the quantity of work to be done.

If the Contractor commence the work, it shall be evidence that he is satisfied with the measurement proposed by the Executive Engineer.

All embankments shall be raised in successive layers of 1 foot depth, slightly concave at the centre and consolidated.

The side cuttings shall never be made nearer than 10 feet clear from the toe of the slope of the bank, and they shall not be continuous, but shall be broken at intervals of not more than 300 feet, by a block of earth not less than 10 feet wide.

The sides of all side cuttings shall be sloped at the natural slope of the soil.

No kunkur shall be quarried in the side cuttings.

In cuttings for hollow roads, the cutting shall always be taken out square to the width of the travelling surface down to the formation level, and the slopes be cut afterwards.

Turfing, grassing, and sodding.—Turfing and grassing slopes and surface with *dhoob* or other grass, or cutting and placing sods.

In turfing and grassing the grass seed may be sown or the roots of

dhoob, khus khus, or other grass planted according to orders, and watered until they vegetate On slopes the seed should be drilled in horizontal lines

Sodding will only be executed in situations where good strong turf sods can be cut within a mile The sods are to be cut nearly of a size, and arranged so as entirely to cover the surface

Sods may be used built as retaining walls to steep slopes, in this case their length, breadth, and thickness must be in the proportion of 6, 3, and 1 inches, they will never be less than 3 inches in thickness, and must be laid in courses alternately header and stretcher, the beds at right angles to the batter, and the successive courses breaking joint with the one below Each course when laid must be beaten down with large flat rammers so as to pack the sods closely, but without breaking them The backing of soil must be built up evenly with the retaining wall, course for course

The rates for sodding will be based on the assumption, that sods can be cut within 300 yards of the work, a charge for extra lead will be allowed, if they be carried more than that distance

No grassing or sodding will be executed to embankments, or other made earthwork, until they have stood one rainy season

---

Brick-work

First class brick-work will consist of first class bricks laid in cement, the bricks to be of uniform size, thoroughly and equally burnt, of a deep red or copper color, not vitrified, ringing clearly—to be well and squarely shaped, hard burnt, and sound

Every brick to be bedded and drawn up in cement, to be laid with a true bond, with only such proportion of half bricks as shall be necessary to complete the bond Every course to be thoroughly grouted

No batts to be used in the brick-work

No joint to be more than three-eighths of an inch in thickness

Every brick to be saturated with water before it is put into the work

When the brick-work is not to be plastered, bricks of a uniform color are to be selected for all face-work

In building brick arches and cylindrical rings of every description, the

voussoir joints are to be properly summered, bricks forming skew back joints are to be moulded or cut so as to radiate truly. The rings are to be bonded with each other, and the whole work executed in the best manner. The rates to include cost of centering up to 16 feet span, above which the cost of centering will be paid for separately according to its construction.

The top of unfinished masonry to be kept at all times flooded with water.

The walls to be carried up regularly in all cases where the nature of the work will permit.

In all cases, returns, buttresses, counterforts, &c., are to be built up course by course with, and carefully bonded into, their main walls. These are never to be joggled on afterwards.

Where the masonry in one section of a building cannot be carried up in even courses, the break is to be left in regular steps, so that the new work to be added may be built on over the old.

The *mortar* to be composed of kunkur or stone lime, mixed with soorkhee or sand, in such proportion as the Executive Engineer may direct, according to the quality of the lime to be used. If necessary a proportion of stone lime will be added to mortar made of kunkur lime. The mortar will be thoroughly ground and mixed under edge stones.

The kunkur lime may be burnt in kilns with charcoal or wood, or stacks with ooplah, as the Executive Engineer may direct.

The soorkhee is to be finely pounded, made from well-burnt bricks or from properly tempered and approved clay or loam, worked into lumps with the hand, and well burnt.

If sand be used, it is to be sharp, coarse-grained river sand, clean and free from clay or earth.

Not less than 24 cubic feet of mortar (dry) to be used to the 100 cubic feet of masonry, when the bricks measure $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{2}''$. More will be required if the bricks be smaller, less if the bricks be larger, but no alteration of the rate will be made on this account.

Second class brick-work will be executed of similar workmanship generally as first-class, but with second-class bricks, viz., of uniform size, burnt throughout of a light red—not straw color.

No joints to be more than half an inch in thickness.

Mortar not to be ground under edge stones, mixed in a trough.

This work will, with very few exceptions, be plastered.

Third class brick-work will be executed with bricks similar to those described for second-class laid in mud.

The execution of the work in bond and other details, to be as for second-class brick work.

The mud to be well tempered—if very plastic, a proportion of sand to be added. To be worked down with water till it is perfectly free from lumps and of the consistency of thick paste.

Fourth class brick-work to be executed similarly to third class, but with bricks not thoroughly burnt, being of a straw color, or what is generally known as peelah.

Minor buildings, enclosure walls, &c., will sometimes be built of sun dried bricks laid in mud, as specified for third class masonry. The bricks must be well and squarely moulded, of well tempered clay or loam, and be thoroughly dried before they are used.

The floors of bakers' ovens are generally formed of 6 inches of sand and salt, overlaid with brick-on-edge, the bricks rubbed so as to form a perfectly close clean joint and laid without cement. One maund of *kurar neemuk*, the salt given to cattle, suffices for 100 superficial feet of floor.

No XL

RAILWAY BRIDGE OVER THE JUMNA, ALLAHABAD

Description of the Sinking of the Masonry piers *By* JOSEPH F. STRONG, ESQ, C E

(Abridged from the Civil Engineer and Architect's Journal)

THE Bridge of which the foundations are described is on the main line of the East Indian Railway from Calcutta to Delhi, and spans the river Jumna at Allahabad, about $1\frac{1}{4}$ mile above its confluence with the Ganges It is composed of fifteen openings of 205 feet clear span each, crossed by wrought-iron girders, and giving a total waterway of 3,075 feet, the distance between the abutments being 3,278 feet, the height of the top of the piers is 58 feet 6 inches, and of the rails 80 feet above low-water level *Fig* 1, is a general elevation of half the length of the Jumna bridge, and *Fig* 2, a transverse section *Fig* 3 gives a section of the bed of the river, the vertical scale being enlarged five times For the foundations of the bridge, ten Brick Cylinders AA, of 13 feet 6 inches diameter, are employed in each pier, sunk to a depth of 43 feet below the low-water level, as shown in *Fig* 4, which is an elevation of one of the piers taken transversely of the bridge *Fig* 5, is a vertical section of the pier to a larger scale, taken longitudinally of the bridge, showing a section of a pair of the brick cylinders *Fig* 6, is a corresponding half sectional plan of the pier taken through the brick cylinders AA, the outline of the pier being shown by the strong dotted line

The Jumna, like most of the Indian rivers, winds about much in its course and varies in width and depth considerably, and within a distance of three-quarters of a mile above and below the railway Bridge, it is 65 and 72 feet deep respectively at low-water, but this depth is reduced to only 15 feet at the spot selected for crossing by the chief engineer, Mr Edward Purser A number of experimental brick cylinders were sunk to ascertain what the bed of the river consisted of, and at a depth of 35 feet, nothing but sand partly mixed with clay was found Generally speaking the water is so low in the Indian rivers between the months of November and May that there are no great difficulties to be got over in beginning operations for sinking the cylinders to form the foundations of the piers, but in the Jumna, which is never dry, it was unavoidable that the piers had to be begun where there was deep water, and as the means of pitching iron curbs under water were not at hand, the question arose, what was the best mode of commencing the building of the cylinders preparatory to sinking them?

The simplest plan seemed to be to form an artificial island for each pier, and this was done in the following manner —Taking the centre of a pier in 15 feet depth of water as the starting point, and setting out a space of 175 feet length by 120 feet width, sand bags were sunk on the down-stream and two adjacent sides, thus forming three sides of an enclosure, in the centre of which loose sand was thrown, which was carried by the stream and deposited against the upper side of the lower boundary of sand bags, where it formed a ridge, in due course the surface of the water was thus reached, when the sand was all thrown on the up-stream side, and an island was thereby speedily formed 100 feet long by 60 feet wide at the top On this island the ten iron curbs were pitched to form the bases for the ten brick cylinders composing the foundations of the pier, being pitched at a distance of 15 feet 6 inches from centre to centre transversely of the pier, and 15 feet longitudinally

The iron curb is shown in *Fig* 7, which gives a vertical section of one of the brick cylinders to a larger scale, showing the cylinders AA partially sunk The curb B is 13 feet 6 inches diameter outside, and 8 feet 6 inches inside, the interior of the brick cylinder diminishing to 6 feet 9 inches diameter The curb consists of a flat horizontal ring of $\frac{3}{8}$-inch boiler plate, 2 feet 6 inches wide, rivetted by an angle-iron to an outer cylindrical ring of similar plate 18 inches deep, and having gusset plates connecting

the two rings underneath The outer cylindrical ring extends 3 inches above the horizontal one, forming a support all round to the base of the brick cylinder on the outside, and an angle-iron upon the inner edge of the flat ring forms a similar support within To keep the curbs in place they are sunk till the top plate of the curb is bedded on the sand, then 12 feet height of brick-work, 3 feet $4\frac{1}{2}$ inches thick, is built upon the curb, the first 5 feet of which are sunk by simply taking out the sand from the underside of the curb by hand, after which the *jham* must be used

The results of numerous trials with many kinds and forms of the tool gave a jham* such as is shown at C, in *Fig* 7 and *Fig* 8 The jham is made of wrought-iron with a scoop 2 feet 2 inches wide, and 2 feet 4 inches long, made thin and sharp at the front edge, and supported by two stays fixed to the sides of the scoop, and also made thin and sharp at their front edges for penetrating the ground readily, the whole weighing about $\frac{3}{4}$ cwt

The mode of using this jham is as follows —By means of a couple of ropes D attached to the tail end of the arm E, the jham is lowered by hand to the bottom of the well, till the cutting edge of the scoop C and the outer end of the arm E rest upon the sand, as shown by the full lines in *Fig* 7 Then with the weight of two or three men bearing on the top of the vertical pole F, which is held in place by the pin at the bottom passing loosely through a hole in the tail end of the arm E, the scoop is raised a short distance by the ropes D, the outer end of the arm resting upon the sand and forming a sort of centre of motion, and the scoop is then dropped with the weight of the men bearing upon it, and its cutting edge is thus forced into the sand By repeating these strokes the scoop is forced into the sand, the workmen knowing by the feel when the scoop is deep enough in the sand Then with the weight of the men still on the vertical pole F, the jham is hauled up by means of the windlass G, round the barrel of which the chain is wound that is attached to the extremity of the arm E, the jham being thereby tilted into position is brought up filled with sand as shown dotted in *Fig* 7 It requires ten men at the windlass to move the jham when bedded and covered with sand, it is then drawn up to the top, when it is emptied, and the process repeated

* The kind of jham employed and the method of using it are very similar to the practice in sinking the piers of the Solani Aqueduct, on the Ganges Canal —[ED]

After the first length of 12 feet of brick cylinder has been sunk down to the water level, an additional 15 feet is added, as shown in *Fig* 5, and the process of sinking continues till the 15 feet added has been sunk, when an additional 16 feet is added, making a total of 43 feet depth. As a precaution for preventing the curb and lower portion of the brick cylinder from parting from the upper portion, which is found sometimes to occur, provision is made on the curb for attaching six holding-up bolts, which are built into the brick-work for a length of 16 feet, as shown in *Fig* 5, and at intervals of every 5 feet a ring of flat iron is dropped over all the bolts and cottered down on to the brick-work.

The rate of sinking of the cylinders is far from regular, at starting the progress is pretty even, the cylinders going down from 15 to 9 inches per day, but the average rate of sinking when down to 20 feet is not more than $4\frac{1}{2}$ inches per day, and beyond that depth the rate of progress gradually decreases till it is not more than $1\frac{1}{2}$ to 1 inch per day of 24 hours. The plan that is adopted where the sinking goes on slowly is to add extra weight on the top of the cylinder, either by building extra brick-work or adding a load of rails. In very bad cases both means are used, till a weight of 40 tons on each cylinder has been added, and even with this additional load on the top great difficulty has been met with when the sinking has reached a depth of 40 feet, which is not surprising when it is considered that there is then a constant pressure due to 40 feet head of water acting upon the sand round the exterior surface of the cylinder at the bottom.

When the cylinders have been got down to the depth of 43 feet they are ready for the concrete H, *Fig* 5, but before throwing in the concrete, a diver supplied with Siebe's diving apparatus is sent down to clear away any rubbish that may be left at the bottom of the well, and level the space under the curbs for the reception of the concrete. A depth of 15 feet of concrete is then thrown in, composed of 1 part of fresh burnt unslaked lime, 1 of broken bricks, and 2 of under-burnt lime, these are the usual proportions of the concrete used in stopping the cylinders, and about 18 days are generally allowed for it to set. A disc made of two thicknesses of 2 inch planking is let down upon the surface of the concrete, weighted by 3 feet thickness of brick-work, this disc is a little less in diameter than the inside of the cylinder, so as to pass freely down on

to the concrete, the space between the edge of the disc and the sides of the cylinder being then filled in with wood wedges driven by divers. The object of putting in this disc is to prevent the concrete being disturbed by the pressure of water underneath, whilst the water is being baled out from above the concrete, preparatory to building the cylinder up solid.

The mortar used was made of 1 part of lime to 1 or $1\frac{1}{2}$ parts of soorkhee, which consists of bricks pounded and passed through a sieve of 8 meshes to the inch; this mortar is of the best description, being hydraulic, and setting almost better in water than out of it.

The next operation after having made tight the wooden disc upon the top of the concrete is to bale out the water, and build up the void inside the cylinder solid with rubble stone, as shown in *Fig.* 5; this is carried up to the top of the cylinders, and their tops are thus reduced to an even bed ready for the covering stones. As a precaution to prevent these stones from spreading, a groove is cut in the top of the cylinders 6 inches deep, and extending length-ways of the pier, as seen in *Fig.* 4; into this groove the large stones are laid, and they stretch across the space between the cylinders, and have a good hold on each cylinder. The stones are all cramped at the joints with $1\frac{1}{4}$ inch square iron, and the stones in the next course above are dropped into joggles in the first course. The hearting of the cylinders is then carried up in brick-work, diminishing by a set-off of $2\frac{1}{2}$ inches at each course to form a core or centre for the corbelling or over-sailing of the brick steining of the cylinders. A similar provision is made on the outside of the cylinders, by throwing in concrete between the cylinders, and building concentric rings of brick-work upon that; over these the corbelling on the outside of the cylinders is carried. There are twelve courses of brick-work between the top of the cylinders and the top of the second course of the covering stones; and at this level there is a through or bonding course of ashlar, running transversely to the piers, as shown in *Fig.* 5. Up to the top of the plinth there are similar courses faced only with ashlar, the backing or hearting being of large rubble. The piers between the plinth and cap are built with ashlar facing to the cut-waters, blocking courses between the shoulders of the cut-waters, and rubble backing behind throughout the whole length of the piers. There are large stones for carrying the cast-iron bed-plates, upon which the saddles supporting the end standards of the bridge rest

The section of the river bed, *Fig* 3, shows the body of water in the river at low-water, and the lower dotted line shows the ordinary rise of the river at flood time, being about 45 feet rise, the level of the underside of the girders is fixed at 14 feet above the ordinary flood level The upper dotted line shows the extraordinary rise of $51\frac{1}{2}$ feet that took place in the years 1838 and 1861 During the time of the last extraordinary flood of 1861, the current of the river increased to the rate of 9 miles an hour, the ordinary rate when not flooded being only 2 to 3 miles an hour

---

In the course of the discussion upon the paper—MR STRONG said,—the means adopted for keeping the cylinders vertical in sinking was to move the windlass round through a quarter of a circle every six hours, so as to take the sand with the scoop from every side successively of the cylinder In taking the sand from the inside, some of the sand outside necessarily got forced in at the bottom of the cylinder by the external pressure, which had also to be got out by the scoop, and this, with the continually increasing density of the sand, was the reason why the rate of progress diminished so rapidly when the depth sunk was considerable

MR H WOODS asked whether any other plan of getting up the sand had been tried besides that described, in order to raise it more quickly He had made about six years ago, for Mr Ward, a set of machines like vertical dredgers, intended to be used on some of the railways in India for getting up the sand in sinking pier foundations, and he believed it was intended to use ten of the machines at a time Each dredger had about thirty light wrought-iron buckets, 12 or 15 inches long, and the same breadth at the widest part, with the mouths steeled, there was an adjustment for sinking the dredger down to work to a depth of 30 feet, and the buckets delivered the sand into a moveable spout worked by a cam, which brought the spout forward to receive the charge of each bucket as it came to the top, and then drew it back again out of the way to allow the empty bucket to pass down clear He did not know, however, about the working of these machines

MR STRONG replied that the dredgers referred to had been used, but

only to a depth of 10 or 12 feet In shallow water they might be used advantageously, but at a greater depth, the inclination was too steep for them to work well The brick cylinders of 43 feet depth, and 6 feet 9 inches inside diameter, had so small space inside for the dredgers that the buckets had not room to deliver themselves in working at a great depth

Down to a depth of 10 feet from the surface of the ground the rate of sinking was about 18 inches per day The cost of sinking each separate cylinder by this plan was 10*s* per foot down to 5 feet depth, between 5 and 10 feet it was 20*s* per foot, between 10 and 15 feet, 30*s* per foot, and so on, increasing regularly 10*s* per foot at every additional 5 feet of depth, down to 40 feet depth, beyond which the rate was 90*s* per foot Those were the rates paid to the men for labor only, the materials being found for them The work was all done by contract one contractor undertook the sinking of one or more cylinders at those rates, and paid his own men All the cylinders were sunk together in one pier, as it was easier and much quicker work to sink them all together

Mr J FERNIE asked what determined the depth to which the cylinders were to be sunk, and whether at the bottom of the deepest pier the material was still the same, or was found to vary

Mr STRONG replied that during the dry season, when the water was low, sections were taken across the rivers, and the depth of the river bed was never found to vary to any great extent, the average greatest depth at low-water being about 15 feet, but the deepest part was seldom found in the same place two seasons running The piers were generally sunk to a depth of 43 feet below the low-water level, and borings had been taken, but nothing but sand was found at a depth of 80 feet below the water level Sometimes the sand was found to be mixed with clay and loose stones, but nothing like rock was ever met with The only failure there had been with the brick piers occurred during the high floods of 1861, when the four up-stream cylinders out of the ten in one pier fell over This was owing to the sand inside the cylinders having been scooped out in the process of sinking to as great a depth as 18 feet below the curbs, so that the cylinders were hanging as it were in their places, held up only by the friction of the sand outside When the flood came down and the water began to eddy round the cylinders, the sand was set in motion and gradually loosened round them, and eventually, the sup-

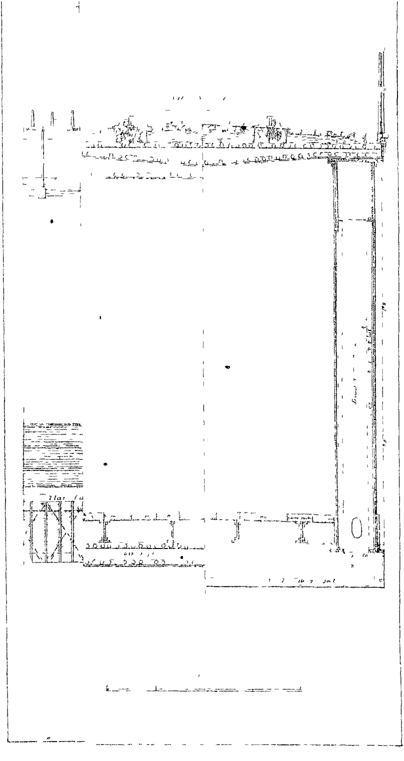
port being taken from them, they slipped down, and in so doing quietly fell over on their sides It was subsequently ascertained by probing with steel rods that the convex side of the cylinders was unbroken, they had simply fallen over, but had not broken to pieces The cylinders had not been replaced when the author left India last year a coffer-dam had already been made round the spot where they lay, and an excavation was being commenced for the purpose of getting down to them When got at they would have to be broken up in order to be removed

Mr F J BRAMWELL suggested that the cylinders might be sunk much more rapidly if they were weighted with an additional load for the purpose, as there appeared to be an objection to increasing the height of the cylinders in order to get a greater weight If they could be made to go down quicker, he thought there would not be so much sand running in from the outside, which was the cause of the delay in sinking, and it would not be necessary to shift the scoop and windlass round several times during the day to make the cylinders go down straight When the shaft of the thames Tunnel, on the Wapping side of the river was sunk, the brick-work was built up to a height of 25 feet on the iron curb before the excavation was commenced, in order to make it go down rapidly and steadily, and it was afterwards loaded two or three times during the sinking, to get it down

Mr H W HARMAN concurred in the desirability of loading the cylinders in order to sink them rapidly, so as to prevent the material outside from getting forced in at the bottom by the pressure of the water He had found some difficulty with the iron cylinders of the Trent bridge, and had loaded them with 35 to 40 tons of railway rails, they then sunk rapidly, and nothing had to be excavated except the material inside the cylinders, as none of that outside found its way in

Mr E A COWPER thought that not only was weighting necessary to sink the cylinders rapidly enough, but a different form of iron curb was desirable, to avoid having such a large at surface flat the bottom of the cylinder, which must oppose a great resistance to its easy descent He suggested that if the outer edge of the iron curb were prolonged considerably in advance of the bottom of the brick cylinder, so as to present a cutting edge all round, the cylinder would then sink faster, because the projecting curb would reach so far down into the sand as to prevent the external sand from getting forced up into the cylinder

Mr STRONG said that no experiments had been tried as to what weight it would take to sink the cylinders deeper in the sand after they had been sunk to their final depth, but they had tried an experiment as to the supporting power of sand under water, for some fear had been expressed at first that if the pier cylinders should ever be left partially unsupported, by the sand being scoured away from the sides, they would under the weight of the piers and superstructure sink deeper into the sand. To ascertain whether this would really be the case, the following experiment was tried. Two ⅜-inch boiler plates, 6 feet long by 3 feet wide, were rivetted together, and 20 holes to a scale of 1-100th of the actual diameter of the brick cylinders were drilled through them in the relative positions of the cylinders in two piers of the bridge. The plates were then bedded on sand, which was kept constantly wet by water standing at the same level, and the plates were weighted till there was a pressure of 18 lbs per square inch, equivalent to 42 feet head of water, on the sand, which was then assumed to represent the actual condition of the sand under the pier cylinders when sunk 42 feet. A model to scale of one span of girders was made, resting on ten cylinders at each end, 1⅝-inch diameter each, the ends of these cylinders were dropped through the holes in the plates, which were drilled slightly larger to let them pass freely through, so that the ends of the cylinders rested on the sand under the pressure of 18 lbs per square inch. The girders were then loaded with weights, and it was found that with a total load of 15 7 lbs per square inch on the cylinders they sunk ⅜ths inch into the sand, and under a load of 31 4 lbs per square inch they sunk 1-16th inch deeper, but from that point up to the heaviest weight imposed of 157 lbs per square inch they sunk no further, the total sinking not exceeding 7-16ths inch, and that weight remained on for three months without the cylinders sinking any deeper. The load of 157 lbs per square inch was equal to 10 tons per square foot, but the actual weight of the foundation, pier, and superstructure was 5,650 tons on each pier, and the total area of the ten cylinders of 13½ feet diameter in each pier being 1,430 square feet, the actual pressure on the foundations was not quite 4 tons per square foot. The experiment therefore proved that the piers were quite safe from sinking deeper in the sand, even under a load of more than double what they had actually to carry.



Description of the Iron Superstructure, abbreviated from "Humber's Iron Bridges"

The design provides for a double line of Railway and Roadway, the rails being carried on the tops of the Main Girders at a height of about 17 feet from the surface of the roadway Each span was intended to consist of two distinct bridges, placed side by side, and each bridge was designed to carry a railway and roadway The structure, however, has only been completed for a single line, though the Masonry and Iron superstructure of the piers have been executed in accordance with the design shown in the plate The Main Girders, of which there are two to each bridge, are composed of the following parts, viz , a top compressive member formed of wrought-iron boxes or cells, a bottom tension flange of wrought iron bars or links, and a web which is of the triangular principle, and consists of a series of wrought-iron struts and ties, the former of which are placed in a vertical position The cross girders for the upper roadway are placed at distances of 1 foot 6 inches apart, and are of the construction shown in figure, those for the lower roadway are placed in pairs at a central distance of 4 feet 6 inches between each pair The platform of the lower roadway, which is formed of a double thickness of 2-inch planking, is carried on 4 wrought-iron continuous longitudinal joists, which rest upon the cross-girders just mentioned, these joists are braced together on the under side by wrought-iron bars 3 inches wide, and ¾-inch thick

TOTAL WEIGHT OF BRIDGE

	Tons	Cwt	Qrs	Lbs
15 Girders,	3,769	15	2	14
14 Platforms,	23	16	0	0
7 sets of bed-plates, with roller arrangements,	124	4	2	7
7 sets of bed-plates for fixed bearings,	99	6	1	0
1 for land pier,	9	15	0	0
1 for land pier,	7	19	1	21
Weight of superstructure for one line of railway and road way,	4,034	16	3	14
Weight of iron-work in piers,	159	4	0	0
Total weight of iron-work in bridge as executed,	4,194	0	3	14

which, for a length of 3,330 feet, gives a total weight of iron per foot run of 1 235 tons

The following are the principal points in the Specification —

The whole of the *Wrought iron* used for the work, is to be free from scales, blisters, laminations, and all other defect No plates, bars, or angle irons, will be approved which are found to exceed, or fall short, of the specified weights and dimensions, more than 5 per cent

The *bars*, and all parts of the girders whatsoever, which may be subjected to tension, are to be capable of bearing a tensile strain of, at least, 20 tons on the square inch of section, under the concussion of a blow struck with a heavy hammer

The *rivets* are all to be of the best quality of Staffordshire rivet iron

The *bolts* and *nuts*, and the *horizontal braces*, are to be made of the Monk Bridge "best," or of Bradley's **S, C,** crown iron, or of such other iron of equal quality, as shall be specially approved by the engineers

The *frames of the expansion roller bearings* are to be forged from Low Moor, or Farnley, or the best Monk Bridge iron

All the *Castings* are to be clean, sharp, true to form, and free from air-holes or other defects The *bed plates* and *rollers* are to be cast from a mixture specially selected for hardness

The *bolt holes* in the bottom bars, and in the diagonal ties, are to be made as follows —Holes not more than $1\frac{1}{8}$ inches in diameter, are first to be punched through the bars, as nearly as possible over the centres of the finished holes, their position having been accurately marked off with a template The bars, in sets of from six to twelve, are then to be stacked on, and bolted firmly, to the bed-plate of a boring tool, made or adapted specially for the purpose In this position all the holes are to be bored, *without the bars being shifted from the bed plate*, the boring tool being passed through the holes punched in the bars, and guided in steel bushes, both above and below the tool

All *angle-irons* whatsoever, not expressly excepted, are to be in single lengths without welds, or joints In the struts and intermediate girders, they are to be carefully bent at a sufficient heat, to the required form without being cut

The *plates of the horizontal boxes* are to be in one length, without joints , and throughout all the girder work no joints or joint plates will be permitted, beyond those shown on the drawings

The *lugs* by which the horizontal braces on the girders are affixed to the top boxes are to be of forged scrap-iron , after being drilled to take the rods, they are to be rivetted on the boxes accurately in the line of the braces

The *braces* themselves are to be rods of $1\frac{3}{4}$ inches in diameter for their general length, but having pieces of rod of larger diameter welded on their ends, to take the screwed portion without reducing that section below that due to a diameter of $1\frac{3}{4}$ inches They are all to be screwed at each end for a length of not less than 6 inches, and provided with double hexagonal nuts

Lower Roadway—1*st* Four rows of continuous wrought iron joists are to be laid from end to end of the bridge, to carry the lower roadway The outside rows consist of bars $7 \times \frac{5}{16}$ with two angle irons at each edge, each $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ The lower flange is strengthened by a plate $10'' \times \frac{1}{2}''$, also running the whole length of the bridge These joists, with the $10''$ plate rivetted to them, are to be sent out complete in 20 feet lengths, the connections between the plates being made as shown

The intermediate joists consist of bars $8'' \times \frac{5}{16}$, with two angle irons, $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ at each edge, to be made up in 20 feet lengths as before.

All these lengths are to be so arranged as to break joint with each other.

The cross girders are to be punched out where these joists cross them, so that they may be rivetted together in India.

These joists are to be braced together on the underside, by wrought-iron bars 3″ wide, by $\frac{3}{4}''$ thick.

2nd. The vertical struts are to be connected together at the lower ends, with plates $\frac{3}{8}''$ thick, 15″ deep, and of such width as will fill up the distance between the vertical angle-irons of the strut rivetted to the struts with four $\frac{3}{4}''$ rivets on each side.

3rd. The end bars of the lower member of the girder are to be stiffened by the insertion between each pair of $\frac{1}{4}''$ bars, of a bar $3'' \times 1''$. All these bars are to be rivetted together.

The pairs of bars on each side of the girder are to be further connected together by $3'' \times \frac{3}{4}''$ bars, forming a bracing as shown. None of the rivetting is to be executed in this country, except what is necessary to form the intermediate bars into a bracing.

Accuracy required.—It is to be expressly understood, that as a rule, the greatest possible accuracy is to be attained in every part of the work, the object being to facilitate the erection of the bridge in India by perfection of workmanship in this country. It is therefore intended that all similar parts shall fit indiscriminately in all similar places and in any span. To ensure this, every similar piece is to be tested on completion, as to the accuracy of its form and dimensions, in a gauge test, and all those that do not correspond with such gauges will be rejected.

Testing.—Every span of the bridge is to be erected rivetted together, and finished complete in every respect, except as regards timber work, on the contractors' premises, so that it may be tested under load. For this purpose it is to be put together upon a timber platform, as specified in the following paragraphs, and bearings are in addition, to be provided at two ends to carry the girders when the wedges beneath the platforms are withdrawn.

These bearings are to be of solid masonry, built upon concrete, and (if necessary), piled foundations, to prevent the possibility of settlement during the testing of the span.

Should any settlement take place whilst the whole or any portion of the load is on the bridge, the contractors will be required to remove all such load, to reinstate the bridge in its proper position by means of the platform wedges, and to recommence anew the testing. The load to be placed is 450 tons of pig iron, $\frac{4}{5}$ths of which are to be put upon the upper roadway, and the remaining $\frac{1}{5}$th upon the lower roadway. It is to be laid upon temporary planks of sufficient strength, and distributed uniformly over the roadway.

On the receipt by the contractors of the Engineer's certificate of the satisfactory completion of the testing, the temporary rivets are to be cut out and the span taken to pieces, packed, and delivered for shipment.

The girders are to be erected on timber platforms, and must rest immediately on cross cills, with carefully-made folding wedges of hard wood beneath each cill, the cills and wedges being sufficiently close to admit of the girders being readily raised or lowered by driving or withdrawing the wedges.

These cills are to be carried on piles, if the nature of the ground renders piling

advisable, or if not, they are to be secured by other means from the slightest settlement

The required camber must be carefully given to the platform in the arc of a circle, the chord or camber in the centre being 4½ inches

Painting—The whole of the materials delivered under this contract are to be painted with two coats of good zinc paint, or of Woolston's Torbay paint, of any color the engineers may desire, one to be laid on as soon after the formation of the parts, and the other subsequent to the taking to pieces of the parts after their temporary erection

The superstructure of this fine bridge was designed by the Messrs Rendel, and executed at the Canada Iron Works, Birkenhead

PECULIARITIES OF INDIAN ENGINEERING.

WITH the present Number is given a Glossary of Indian terms used in the First Volume, chiefly for the benefit of subscribers in England, and on the same account also, I propose to draw attention to some of those peculiarities in Indian Engineering, which will serve to show the conditions under which work has to be executed in this country, and how far they differ from English methods, the sketch will not, perhaps, be altogether destitute of interest to many who are in India

First, as to the Agency —Except Forts, Arsenals, Dockyards, Barracks, and the like, there is scarcely a single Public Work in England in which the Imperial Government is directly interested, for even such works as Jails, Roads, &c, belong to the counties, or to recognized local interests, while the great mass of important works, such as Railways, Harbours, &c, belong to Joint-Stock Companies, and are private property

In India, the Government is the constructor and maintainer of nearly every public work throughout the country Not merely works which specially appertain to an immense Military Establishment, but every Road, Bridge, Church, Court-House, Jail, &c, has to be built from Imperial Funds, and through Government Officers Nor can even the Railways be excepted, for though the capital employed is not its own, yet the controlling power possessed by Government is so great,* that not the smallest work can be under

* This arises from the Guarantee system under which the capital has been raised, the Government guaranteeing a minimum rate of interest (5 per cent) to the shareholders on all sums passed to capital account. The controlling power is exercised through the Government Consulting Engineers, who have a veto on almost every action of the Company's Engineers The system, though perhaps the best that could be devised at the time, has been productive of much delay, and no little dissension It would be a

taken, nor the salary of the least official paid without its written authority

For the above work, a great Department of State, the Department of Public Works, is specially provided, by which a systematic control is maintained over a vast body of officials, European and Native, acting as Engineers, Overseers, &c, from the Secretariat down to the meanest *employé*

But another distinctive difference between the Agencies employed in England and India is, that in the former country, work is executed almost invariably by contract, while in the latter, daily labor employed and paid by the Engineers is as invariably used It is true that every effort is being made to introduce the contract system, and that it is generally in vogue in the Presidency Towns, and on most of the great Railway Works, but over the whole country the vast mass of the Government work is done by daily paid labor, and the extra work thereby thrown upon an Engineer may be easily conceived

In another very important matter do the functions of the Indian Engineer differ much from his brother in England In many parts of the country there is no organization of labor whatever, and when works have to be executed, the Engineer has to collect and train his workmen, to make arrangements for carriage,* to make his own bricks, burn his own lime, cut his own timber, and in a word superintend a hundred petty details, which in a civilized country are

preferable course for Government to grant a certain subsidy to the Railway Company for every mile of line, as completed and open for traffic, and some such arrangement will probably be adopted in future

* This difficulty of carriage alone, in a country where the distances are so vast, and the means of inter communication so incomplete, is most serious The greater portion of the Permanent Way on the East Indian Railway was brought by Native boats up the Ganges, and £100,000 worth of rails, &c, now lie at the bottom of that river On the Punjab Railway, the materials were brought in boats up the Indus, which were often seven months on the voyage (800 miles), the cost of freight between Kurrachee and Moultan being *double* the freight from England to Kurrachee The locomotives after getting to Moultan, were dragged up an unmetalled road to Lahore on trucks, by elephants and bullocks—six weeks being occupied in accomplishing the 200 miles On this line too, which runs through a desert, the first steps of the Engineer were to dig wells and build huts for the workpeople, and induce grain merchants to live in the desert to supply their wants When the writer went down to inspect the first trace of the line with the Chief Engineer, water and provisions had to be carried on camels to supply the whole party

undertaken by a hundred different men, each skilled in his own peculiar business.

Of the Workmen themselves, much good may be said. That they have the usual prejudices of ignorant men to the introduction of new ideas, and new methods of working, is to be expected, but they are not worse than others in that respect, and if well managed, are as a rule both intelligent and teachable. Excellent masons, carpenters, and smiths abound in the country. The machinery in the various Railway Workshops is managed by Natives under European superintendence, and though there are no Native engine-drivers as yet, we shall doubtless have some before long.*

The most striking thing to the Engineer fresh from England, is the total absence of the ordinary mechanical appliances for executing work. Vast earthworks are still made by the help of the *phowrah*, or native spade, and baskets carried on the heads of women and children. Wheelbarrows are scarcely ever seen, horse carts still more rarely. For getting water out of foundations, &c., pumps are coming into use, but in general the primitive native modes of baling, or the *Churrus* (leather bag) or Persian wheel worked by bullocks, are still employed. Bricks and Tiles are almost invariably hand-made, and the pug mill unknown, the saw-pit is never used.

Of course the principal reason for this is the comparative cheapness of labor, but if the rate of labor increases for a few years longer, as it has done for some time past, the introduction of more elaborate appliances will become essential. At present, except the Railway Workshops and those established at Roorkee, there is no Steam Machinery in the country, unless at the Presidency Towns. Machines driven by wind power are also unknown, it is difficult to say why. Of the enormous water power available on the numerous canals and rivers, very little is utilized. Sawing Machines are here

* In the Railway Workshops at Lahore, a short time ago, I saw the carpenters working at regular benches instead of in their own *squatting* position, and turning out some beautiful specimens of work. The whole of the Rolling Stock (except the iron work, which is brought from England,) has been made at Lahore for this line by Native workmen.

At Goojranwalla I saw a Colt's Revolver, copied so exactly even to the engraving on the cylinders, that only very close inspection could tell it had been made by a Native smith.

and there put up, and the common *Punchukhee*, or native corn-mill, is everywhere seen where there is an available fall. Machinery worked by animal power is confined to water-raising for Irrigation purposes, and to one or two primitive inventions employed on Manufactures.

Having said so much of the Agency employed, let us glance at the materials used and the works turned out. In Central India and the Hilly Districts all over the continent, many varieties of excellent building Stone exist, and are abundantly used. In the great plains of Bengal, Hindoostan and the Punjab, however, Brick is the only available material. The English sized bricks or those of a still larger size are now coming into general use. The Native bricks are very small, excellently burnt, laid with little attention to bond, and with a profuse expenditure of mortar. Bricks are burnt with wood fuel* in kilns of several kinds, or in stacks like English clamps with dried cow-dung instead of coal.

Excellent lime is everywhere abundant, produced either from limestone "in situ," or the boulders found in hill torrents, or the kunkur found in the plains. It is mixed with various substances for mortars, of which pit-sand and soorkhee (pounded brick) are the chief ingredients. For very strong or fine mortars, coarse sugar and egg-shells are sometimes added.

A great variety of fine Timber is found in India, generally brought from the forests in the Hills—among which may be noticed *Saul*, a dark, heavy, straight and strong wood, and *Deodar*, nearly the same as the Cedar of Lebanon, the former used in the North West Provinces, the latter in the Punjab for every kind of building purpose. Both of these are found in the hills, alone, at an elevation of from 2,000 to 5,000 feet, the trees are cut down and thrown into the rivers, and when these rise the logs are floated down to the plains. In West and South India, *Teak* is in general use. It abounds in the forests of Burmah, being one of the most valuable productions of that Province. *Toon*, an inferior sort of Mahogany, is exten

* Except in the few places where coal is found. No coal worth working has yet been discovered in Northern India. The locomotives burn wood, and fuel is scarce and dear.

sively used for furniture, *Sissoo* or *Sheeshum*, and some of the varieties of Acacia, are hard, heavy, crooked woods, used for strength and toughness

Iron ores of fine quality are abundant in many parts of India, but from the want of fuel and carriage are little worked, and English iron is generally used Government have made, and are now making, several praise-worthy attempts to develope the manufacture of iron

Here it may be as well to note one or two specialities of Construction employed in India

In *Roads*, stone metalling, laid as in macadamized roads, is common enough, but in the great plains of Upper India the peculiar material *Kunkur* is used, and laid in a peculiar manner It is a species of concretionary oolitic limestone, found in beds close to the surface, and has to be drenched with water, rammed quite smooth, and then suffered to dry before any traffic is admitted It then makes a white, smooth, and very excellent road covering

In Southern India, Laterite and *Moorum*, a sort of red gravel are commonly employed

In *Foundations*, piles are rarely employed, for so many destructive agencies are at work that they would not be lasting The majority of the water-courses are nearly dry at one time of the year, and this affords great facilities for getting in the foundations of Bridges or other works in water For these the general substitutes for piles are Masonry Wells or Blocks, which are sunk close together, arched over, and on them the piers and abutments are raised, they are also used as foundations for houses in places where the soil is very treacherous The beds of most rivers in Northern India when bored, show sand to an immense depth In Bengal alluvial mud is found to as great a depth, and necessitates as much precaution as sand The dry state of the river beds also gives great facilities for turning arches without the use of expensive centerings. A simple arrangement of dry bricks and timbers are constantly used, built up in the bed of the stream, of course the work is subject to accidents from sudden floods, but these are very rare.

The greatest Works as yet executed in India, belong, as in England, to the Railways. Indeed there are none in the world more interesting or important than the Bhore Ghât Incline, the Soane and the Jumna Bridges, and other works little inferior to them, which might be enumerated. The East Indian Railway, 1,000 miles long from Calcutta to Delhi, with the branch to Jubbulpore, now under construction, is probably the longest line in the world owned by a single company, as it is certainly one of the greatest triumphs of Engineering. The Great Indian Peninsular, and other lines, though inferior in length, are some of them, at least, of equal Engineering interest.

With them may be classed the great Roads, though the system like that of the railways is still far from complete. The Grand Trunk Road from Calcutta to Lahore, 1,300 miles in length, comprises every variety of construction, from the heavy gradients through the Rajmahal Hills, to the massive and level embankments between the Jumna and the Sutlej. The Lahore and Peshawur Road, a continuation of the Trunk line, 270 miles long, and now rapidly approaching completion, may challenge comparison with any in the world, while in the formidable extent of drainage crossed by it, it probably stands alone. Of others, the Hindoostan and Thibet Road when finished, may take its place by the side of any of the famous Alpine Roads, while the great Deccan Road, the Assam Road, and many others still in hand are works of considerable magnitude.

Besides the length of the distances to be traversed, it is in the formidable character of the flood waters that have to be crossed, that the specialities of their construction are to be sought. Nothing but actual experience will convince the English engineer of the enormous water-way required to pass drainage lines, which, seen only in the dry season are so shallow and often perfectly dry, and scarcely a season passes without the most ample experience being set at naught by the results of some extraordinary flood. The Indus has been known to rise 50 feet in a single night, where confined between its rocky banks at Attock. At a distance of 800

miles from its mouth, I have been in a boat in the middle, and was unable to descry either shore, while the deep channel in one single season has shifted its place laterally as much as 3 miles. Cross this river in the dry season and the track lies over 10 miles of quick-sand and mud, while a channel of 1,000 feet in width passes the whole body of water. To carry a road across the valley of such a river, and to bridge such a stream, may well daunt the boldest Engineer.

This describes the rivers of Northern India only, those of Southern and Central India have also their peculiarities which it would be tedious to detail here.

It is, however, in the great Irrigation Works that have been or are being constructed in India, that the peculiarities of Indian Engineering are more especially to be sought, for, except in Italy, those works have no counterpart in Europe. The Ganges Canal, 900 miles long with its branches, and pouring its waters over a million of acres through 3,000 miles of distributing channels, the East and West Jumna Canals, 200 and 500 miles long, respectively, the Baree Doab Canal, also 200 miles in length, are works of which any country may be proud, and in the principles and construction of which Engineers have to learn much which they cannot be taught in England. An entirely separate class of works are the great Weirs and Tanks of Madras, whereof the works on the Godavery are the finest examples, and which are also purely Indian specialities.

Next, a word may be said as to Indian Architecture. The Architect and Engineer are generally one, and he also is the constructor as well as designer. The requirements of the climate necessitate modes of construction differing from those in England, but until lately we have not managed to combine coolness and ventilation with much Architectural beauty. A reform in this respect is however in progress. We are at least erecting handsomer buildings, and attention is being directed towards cooling them effectually. The difficulties are great, for what does for the moist heat of the Lower Provinces will not answer for the fierce dry heat of Upper India, which it is necessary to exclude for many

months all day long, unless the air is artificially cooled before being admitted * Moreover, the cold in the winter is often excessive, the average extreme range of the thermometer between summer and winter being fully 100° in the Punjab, while in Bengal the temperature is much more equable, the range not exceeding 70°. With all these draw-backs however, many fine public buildings have been completed, many more are being constructed and projected, and Churches, Railway Stations, and Government Offices are rising fast, which would do no discredit to any capital

Some specialities of construction which are common to most Indian buildings attract the attention of the new comer Except in the Presidency towns, they have no upper-storey, partly from considerations of expense and partly because the upper-rooms get very hot during the dry months The roofs are either thatched or tiled, or else are flat and covered with brick and lime plaster The thick beams supporting the roof, are as a rule left exposed below, as ceiling cloths are apt to harbour vermin and conceal the depredations of white ants The room walls are very rarely papered, being usually plastered and white-washed Wooden floors would be too perishable and dear, so floors of flat tiles or of lime plaster are substituted. Doors are numerous and are invariably double, opening in the middle. Verandahs all round a house are considered indispensable

In many of the most important and interesting branches of Engineering little has been done as yet in India, in Drainage, Water Supply, and Gas Lighting, we are now only making a commencement even in the Presidency Towns A fine scheme is however in progress for the Drainage of Calcutta, and a similar project will shortly be submitted for Madras, while the drainage and conservancy of Native towns, and European cantonments are engaging much attention

In the improvement of our great Rivers for inland navigation, little or nothing has been done, but many Navigable Canals are at work in Madras and Bengal, and others are in progress In Bengal, Inundations from the sea and rivers have also given us

* The temperature of the air at *midnight* in Upper India during the months of May and June is often over 100°

practice in the important subject of Embankments, and the Hidgelee Sea Dyke, when completed, will, it is said, be a noble work

Of Military Engineering not much has to be said Like the Romans of old we encamp our troops in the open instead of shutting them up in Forts Our Arsenals are for the most part inside old Native Forts slightly improved, and except Fort William and the outposts on our N W Frontier, there is scarcely a single Fort of modern construction in the country

Closely allied as it is to Engineering, a word must be said in praise of that noble work the Indian Survey, of which too little is known to the scientific world The report and map in the present number will give some general idea of what has been done, and I am in hopes of inducing some one of our accomplished Survey officers to give me a paper describing the modes of working and the results turned out While the Trigonometrical Department is covering the country with a net-work of triangles, fixing the position of the principal stations with an accuracy that has not been surpassed (if it has been equalled) in any European country,* the Topographical Department is busy in delineating the features of the Mountain Districts in a series of maps,† whose fidelity is only equalled by the difficulties which have attended their completion, and the Revenue Department is mapping the plains to a degree of detail which shows not only every village but every *field* in each village

Incomplete as this summary has been, I cannot take up more space to make it more elaborate, but I will hope that it may be useful in arousing some interest in my subscribers in England in the peculiarities of Indian Engineering

J G. M

* The Supdt G T Survey, Major Walker, R F, has lately proceeded to Europe to confer with the Russian Government on the means of connecting the great series of Indian triangles with that of the Russian Survey

† The Map of Cashmere lately completed by Capt Montgomerie, R F, has elicited the warm approval of the distinguished president of the Royal Geographical Society Many of the Trigonometrical Stations were above the line of perpetual snow, where the Surveyors had to stay for days together waiting for favorable weather for their observations

No XLI.

EUROPEAN GENERAL HOSPITAL, BOMBAY

Designed by CAPTAIN H ST. CLAIR WILKINS, R E

COMPETITIVE designs for the European General Hospital were called for by the Bombay Government in 1863, from Architects in England and India Estimates were also called for, and the cost of the building was not to exceed Rs 3,80,000 Seventeen sets of plans were received, including five or six from England A Committee was appointed to adjudicate upon the designs, for which two prizes were offered, Rs 2,500 for the best, and Rs 1,000 for the next in merit

The Committee awarded First in Merit to the design here illustrated, but stated their opinion that none of the designs submitted complied fully with the conditions, as their cost would exceed the amount specified The Bombay Government replied that they did not wish to withhold the premiums The Committee then, contrary to all practice, melted the two prizes in one crucible, and divided the contents amongst seven competitors

The author of the design given in the present number naturally declined to receive the mutilated premium offered Competitions are objectionable for many reasons, but if it be considered desirable in this country to seek out Architectural talent, which would otherwise lie dormant, it would be better to offer the usual Architectural fees, (viz, $2\frac{1}{2}$ per cent for plans,) authorized by the Architectural Association in London, and when competitors comply *bonâ fide* with the conditions specified, the prizes should not be withheld

Descriptive Remarks

The Hospital is designed in the Gothic style of Architecture, which the author believes to be the style of all others best suited to the requirements of a tropical country. Arcades are always pleasing, and arcaded verandahs or screens of a variety of forms and sizes are obtainable in this style. In the present design, that type of Gothic worked out in the South of Europe in the middle ages has been preferred to the more Northern type, the architectural requirements of India being more nearly allied to those of Italy than of England, various modifications of this style now universally adopted to meet modern necessities have been made. The design will also show that the author is not opposed to judicious eclecticism, and he is bold enough to avow it. In Italy the roofs of Mediæval buildings were generally low, which is to be attributed more to classic tradition than to the direct effects of climate, the roof of this building has been designed at an elevation of 45°, to throw off speedily the heavy rain of Bombay.

The Hospital is 480 feet in extreme length, and $145\frac{1}{2}$ feet in breadth at the centre, the projecting end terminations are $68\frac{1}{2}$ feet in breadth, the ordinary breadth of the building being $58\frac{1}{4}$ feet. The building is entered at the centre on both the East and West facades through covered carriage Porches, that on the West carrying above a small Chapel. An open Arcade leads from the portico steps into a large Octagon Hall, in which are placed two flights of stairs conveniently situated for those entering the building from opposite sides. The two flights are carried up to the upper floor of the building, and they are lighted from above by four rose Windows. To increase this moderate light to a strong one and to add to the vertical ventilation of the building, as well as to produce a feature giving by its external appearance a unity of effect to the whole, which otherwise from its enormous size would be wanting in that unity, a lofty octagonal Lantern has been designed as the crowning member of the composition.

The urinaries, though included in the main building are completely cut off from the wards. Lofty openings slightly screened by shafts and simple tracery admit of a very thorough ventilation.

The building was intended to be constructed of Coorla rubble, a reddish trap, the arch rings being formed of alternate stones of Porebunder

(whitish lime-stone) and blue Basalt. The roof to be of iron, well ventilated, with numerous Dormer windows above the ceilings fitted with ouvers

SCHEDULE OF MEASUREMENTS—GROUND FLOOR.

Verandas 11 feet clear all round

Left Wing

	Feet
Hospital Sergeant's bed room, partitioned off, ..	29½ × 23
Hospital Sergeant's Store,	35 × 23
Apprentices (3), .	22 × 23
"	22 × 23
Dispensary,	19 × 23
Receiving Room, ..	29 × 23
Entrance Hall, with stair-case,	38 × 29
Back and front verandas at entrance, ..	9 feet wide

Right Wing

Assistant Apothecary's bed room, partitioned of, .	29 × 23
Apothecaries' Quarters, " .	31½ × 23
Steward's Quarters, " .	31½ × 23
Matron's Quarters, " .	20 × 23
Women of doubtful character, . .	25 × 23
Private Room,	8 × 23
Receiving Room, . .	10 × 23

At each end, an open passage, 20 feet wide, with free thorough draft of air, connects the baths and urinaries with the main building

In the rear a Porch 38 × 22, and beyond it a room 38 × 13

The front porch is not shown, a small Chapel might be constructed over it, dimensions at the discretion of the Architect.

FIRST FLOOR

Left Wing

Naval Seamen, . . .	66 × 23½
" . .	65½ × 23½
Merchant Seamen, ...	29½ × 23½

Centre

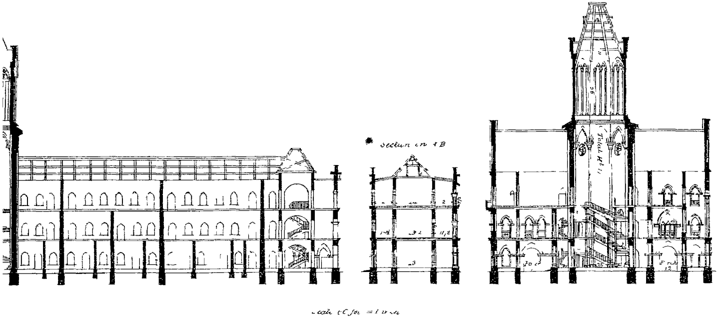
Stair-case, ...	38½ × 29

In Rear

Open passage with free current of Air to Baths and Urinaries, ...	38½ × 22½ 38½ × 13½

BOMBAY GENERAL HOSPITAL.

SECTIONS



Right Wing

	Feet
Merchant Seamen,	64 × 23½
Surgery,	32 × 29½
Female Ward,	66 × 29½

At each end, open passage and bath, &c, corresponding with those on the ground floor

SECOND FLOOR

Left Wing

Paupers, ...	67½ × 24
Military Patients,	66 × 24
Warrant Officers,	30 × 24

Centre

Drawing Room,	22 × 29½
Stair-case,	16½ × 29½

In Rear

Bed Room,	25 × 23
Dining Room,	25 × 12
"	13½ × 23
Bath Room and W C,	13½ × 12

Right Wing

Warrant Officers,	30 × 24
Steam, Telegraph and Mint Departments,	66 × 24
Clerks of Public Offices,	67 × 24

At each end, open passage and bath rooms, &c, as on the ground floor

ABSTRACT

c ft		R	A	P
111,920	Excavation, at Rs 1 per 100,	1,119	3	2
111,920	Filling foundation of rubble-stone and lime masonry, at Rs 18 per 100,	20,145	9	7
34,768½	Plinth of do, of rubble stone and lime masonry, at Rs 20 per 100,	6,953	11	2
115,348	Superstructure, ground floor, at Rs 23 per 100,	26,530	0	7
99,685	Superstructure, 1st floor, at Rs 25 per 100,	24,921	4	0
81,210	Superstructure, 2nd floor, at Rs 28 per 100,	22,738	12	9
8,790½	Brick masonry, at Rs 30 per 100,	2,637	2	4
21,187¼	Cut-stone masonry, ground floor, at Rs 2 per foot,	42,374	8	0
1,133	Cut-stone pillars and caps, 1st floor, at Rs 3 per 100,	3,399	0	0
6,887½	Cut-stone arches, 1st floor, at Rs 2 per 100,	13,775	0	0
691	Cut-stone pillars and caps, 2nd floor, at Rs. 3 per 100,...	2,073	0	0

		R	A	P
c ft				
4,592¼	Cut-stone arches, 2nd floor, at Rs 2 2 per foot, ...	9,759	1	0
s ft				
14,757¾	Doors and windows, at Rs 1 12 per foot,	25 826	1	0
189,300	Chunam plaster, at Rs 7 per 100,	13,251	0	0
c ft				
262¼	Cut-stone steps, at Rs 1 per foot,	262	8	0
s ft				
980	Cut stone pavement, at Rs 75 per 100,	735	0	0
No				
186	Steps in staircase of lantern, at Rs 15 each,	2,790	0	0
2	Staircases for bath-rooms,	744	0	0
s ft				
840	Weather boards, at Rs 80 per 100,	672	0	0
r ft				
1,704	Parapet walls on top of veranda, including 2 feet masonry below, at Rs 5 per 100,	8,520	0	0
3,684	Cut-stone cornice, at Rs 2 per foot,	7,368	0	0
s ft				
40,694	Plank floors, at Rs 114 per 100,	48,832	12	9
17,720	Iron roofing to main rooms, at Rs 50 per 100,	8,860	0	0
17,540	Iron roofing, verandas, at Rs 75 per 100,	13,155	0	0
7,584	Ceiling to main rooms, at Rs 20 per 100,	1,516	12	9
9,159	Paving verandas, bath rooms, &c , at Rs 40 per 100,	3,663	9	7
7,268	Chunam floor for main rooms, at Rs 25 per 100,	1,817	0	0
1,368	Shafts in front of lantern, at Rs 2 per foot,	2,736	0	0
3,266	Shafts in front of bathing rooms, &c , at Rs 1 per foot,	3,266	0	0
	Total Rupees,	3,20,442	0	0
	Add for completing lantern to a height of 145 feet with all the gables and other ornaments,	41,458	0	0
	Contingencies, at Rs 5 per cent,	18,095	0	0
	Grand total, Rupees,	3,79,995	0	0

No XLII

VAULTED ROOFS IN SIND.

Memorandum on Vaulting Roofs with Hollow Voussoirs, without the aid of Centering By LIEUT -COLONEL FIFE, R E

IN a description of the "Syrian roof," at page 69, of No VI of the "Roorkee Papers," it is suggested that voussoirs might be made hollow and accurately shaped, and as I adopted this plan myself in 1851, in vaulting the roofs of buildings in Upper Sind, a description of the method employed in making the voussoirs, and the degree of success which attended their use, may be interesting to those who are called upon to construct buildings where insects destroy wood-work very rapidly, or where seasoned and sound timber is not readily procurable

In Upper Sind there is no Teak wood except what is brought up from the Sea coast, far south of Sind, at enormous cost, and there are only one or two kinds of indigenous timbers which are even tolerably secure from the ravages of the white ant

Upper Sind being almost a rainless country, a terrace roof of a very common construction, and covered with mud plaster was generally used The destruction of the wood-work by insects, however, was so rapid, and the weight of the mud plaster so great, that the falling in of a roof was really almost a daily occurrence, and among even the very small number of European residents there were some very narrow escapes, notwithstanding the constant watch that was maintained over the roof timbers A shower of rain, when it did come, invariably brought down some roof or other from wetting the clay plaster, and increasing the weight over a beam which was previously on the point of falling, and nothing was so

common in Brigade Orders as "the Executive Engineer will be pleased to to replace 14 (or 20 as the case might be) beams which have given way in the———— Barracks"

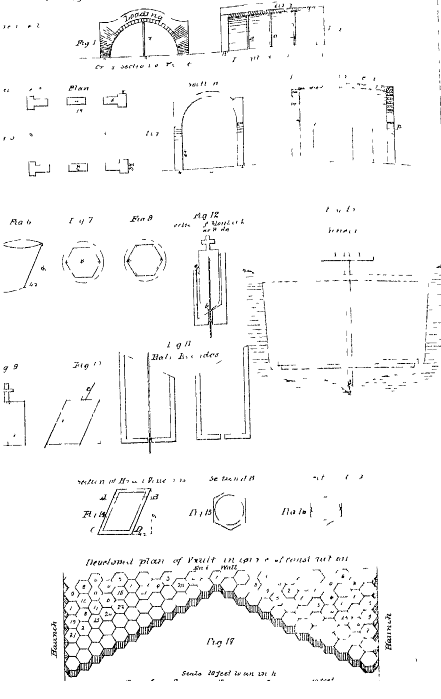
This very unsatisfactory state of things led me to think of the "Syrian roof," a very interesting description of which had been written by Major Underwood, of the Madras Engineers, and published in the first number of the "Corps Papers" Then it occurred to me that by adopting the principle of the hollow tile, but making it a complete voussoir, and hexagonal in shape, and cutting its ends off obliquely, a still more perfect construction might be attained, which would be stronger than the Syrian roof, and more economical from not requiring the aid of centering I therefore turned my attention to the making of a hollow hexagonal voussoir with its ends obliquely cut off, and after a great many failures, succeeded in making one which answered extremely well It was only one-fourth the weight of the solid voussoirs, and could not be made lighter without making it too weak, and its oblique shape admitted of its being used much as thin bricks are used in Upper Sind and in other parts of India, as well as in Italy, for constructing vaults without the aid of centering

In order to ascertain whether a vault made with these voussoirs was really as strong as it promised to be, I constructed a semi-circular vault of 15 feet span from haunches, 5 feet in height, resting on the ground (*see Fig* 1) and loaded it with sun-dried bricks till they were $1\frac{1}{2}$ feet deep over the crown, and rather more over the haunches The bricks were loosely piled without cement and the vault settled by measurement (ascertained from the rods *a*, *a*, *a*, previously fixed) half an inch at the crown during the process The loading was removed after three days, and the vault was taken down only two out of the 700 voussoirs employed were broken, and the injury that occurred to these was evidently owing to their being originally faulty, one being mis-shapen, and the other imperfectly burnt The load carried by the voussoir part of the vault was 13 tons

To get some idea of what thickness of wall would suffice to carry such a vault, a small building, *Figs* 3, 4, 5, was constructed The span was 12 feet, and the thickness of walls $1\frac{1}{2}$ feet The walls it will be noticed were very light from being pierced with openings This building was allowed to stand for six weeks It appeared clear from the result of this experiment, that the veranda of a building vaulted on this plan with

VAULTED ROOFS IN SIN[illegible]

Plans for making Vaulted Roofs of Hollo[illegible]



walls like those in common use in Upper Sind for verandas, would act as a flying buttress to the main vault.

Several buildings were constructed on this plan both by myself and my successors, and where there was a reasonable amount of supervision the result was invariably satisfactory. Of course, without proper supervision, the voussoirs may from carelessness be made almost as heavy as solid ones, and a bulging wall is the inevitable result.

In the buildings latterly constructed, no binding brick arches* at intervals were used, as they were found to be unnecessary, and unless made so small in span as materially to interfere with the interior space of the building, they increased the thrust against the walls.

The largest building on which the plan was tried was the Collector's kutchery at Shekarpore. This building contained eighteen rooms of 18 feet and 20 feet in width or span. The vaults were plastered outside with lime as the building was of a permanent construction.

As an instance of the rapidity with which a building thus vaulted may be constructed, I may mention that I constructed a District Bungalow, consisting of two rooms of 18 feet span, with veranda rooms all round, in less than five months from the date of receiving the order, and there was no appearance whatever of the work having been hastily or badly done, and no repairs were ever needed, except the usual mud plaster to the exterior, which has to be annually inspected, and renewed where the rain may have washed it off. The only timber used in the building was for the doors and windows, and much difficulty was experienced in getting even this small quantity of seasoned timber. Had a timber roof been used, the building could not have been completed in less than a year, and even then the timber would not have been properly seasoned.

The vaulted roof used to cost Rs. 8 per 100 square feet, measured on the voussoir portion only, which was about equal to the area of the floor of each room. This rate covered the outside plaster of mud. Where lime plaster was used, of course the vault cost proportionally more. The bricklayers became very dexterous at last in using the voussoirs, and the roof of one of the rooms (18′ × 22′) of the District Bungalow, was vaulted in two days by two bricklayers.

The Syrian roof of course possesses the same advantage of quick construction, where seasoned timber is not procurable, but it is not quite so

* Binding brick arches at intervals are recommended for the "Syrian" roof by Major Underwood.

quick as the voussoir plan, as the construction and removal of the centering occupy time

The Syrian roof possesses superior simplicity in the preparation of the material, as natives can already make the cylinders required In fact, every potter at his wheel makes the clay which is to form the chatty pot or almost any thing else, go through the single cylinder form before it arrives at its final form, and the manipulation the clay undergoes while on the wheel, renders the cylinder as sound and equal in texture as the best voussoir I could make in a mould

The, I fear, rather tedious description I have given below, of the mode of making the voussoirs should not, however, lead to the belief that the plan is too troublesome to be attempted under ordinary circumstances The making of the voussoirs cost me far more trouble than any thing else, and I have therefore thought it right to give the minutest details But if the making of a chatty pot, which is sold for a pice in the bazaar, were described with equal care, the description of the simple process would also be long

The echo, which is an objection to vaulted roofs in dwellings may be reduced to such a degree as to be unobjectionable by ornamental mouldings in the wall and ceiling-plaster, or by nailing a cloth ceiling to the ceiling-plaster

Where rapidity of construction is aimed at, it is perhaps hardly necessary to mention that the construction of the voussoir moulds or cylindrical tiles, whichever plan may be adopted, should be commenced at the same time as the foundation, otherwise the material for the roof will not be ready by the time the walls are raised

I may mention, in conclusion, that light and nicely balanced as the Syrian and hollow voussoir vaults are with the heavy haunch and light crown, the thrust should by no means be disregarded In small vaults the cohesion of the cement bears so great a proportion to the weight of the voussoirs, that practically there is no thrust, but in large vaults the thrust is considerable Nothing however is easier than to provide for this, by using buttresses * either for the main or verandah walls, and such additions will more often improve than injure the architectural effect In designing vaulted buildings, great strength may be secured also by placing the cross walls in such positions as to make them act as buttresses

* Or wrought iron tie rods, as in the case of an ordinary arched roof — [ED]

DESCRIPTION OF THE METHOD OF MAKING HOLLOW HEXAGONAL VOUSSOIRS, AND VAULTING ROOFS WITH THEM

To form the moulds, a solid wooden vousson is first made in the following manner —A piece of wood about 15 inches in length, and 9 inches in diameter, is shaped into a tolerably accurate cylinder Its ends are then sloped off, till it becomes oblique, as shown in *Fig* 6 Hexagons are then inscribed in circles of about 8 inches diameter, at each end, (*Figs* 7 and 8,) care being taken, by previously drawing a straight line from top to bottom of the cylinder, to make the hexagons parallel From the sides of the hexagon at the bottom, half an inch or whatever may be required, is cut off (*Fig* 8) The superfluous wood is then pared away, leaving the solid vousson, as shown in *Figs* 9 and 10, a piece of wood being inserted at the broad end as a handle

Some common earthen *koondas* (*Fig* 11) are then made, in the ordinary manner, having their tops sloped at the same angle as the vousson, but accuracy in this case is not necessary When the koondas are dry, they are sawn in two, after this they may be burnt They may also be made of wood, but the earthen ones only cost a few annas each, and are not liable to warp

To make the moulds, clay mixed the day previous, and containing rice bhoossa, to prevent cracking, is beaten into flat cakes with the hand, and placed in the half koondas, and well pressed against the sides and bottom with the hand The two pieces of koonda are then bound together with a piece of rope An iron rod something less than a quarter of an inch in diameter is then inserted into a hole at the centre of the bottom of the koonda Next, the wooden vousson, which has a hole bored through it for the reception of the rod, is forced into the koonda, pressing the clay against the sides and bottom This is repeated four or five times, care being taken to keep the vousson wet, to prevent it adhering to the clay If there appears to be too little clay in the koonda, from the cakes having been too thin, more can be added, until the wooden voussoir by compressing it, forms a mould as accurate as itself The voussoir ought to be carefully withdrawn from the mould, otherwise the mouth will be spoiled

The mould ought not to be removed from the koonda for four or five days, as the mass of clay being great, it is liable to crack, it ought, moreover, to be kept in the shade, and while drying, any cracks that may appear ought to be stopped with moist clay As the moulds are re-

moved from the koondas, the weight may be greatly reduced by taking an adze and paring the exterior into the form of a hexagon, corresponding with the inside of the mould When they are dry, holes should be made in the bottom, to correspond with the tenons on the wheel (*Fig* 13) on which the hollow voussoirs are formed By doing this before the burning, much labor is saved, the dry clay being easily cut with a chisel The moulds may then be burnt Litter is the best fuel for this purpose, wood creating too great a heat, and causing them to lose their shape from fusion

Two coolies, after a few days practice, will make from six to eight moulds per day, and a carpenter can reduce the weight, and otherwise complete fifteen in the same time A great number are required, but this is only troublesome at first, for they last a long time If they do break, it is in the burning, or the first or second time they are used afterwards, and the damage is always caused by carelessness in not mixing the clay well, or in not pressing it into the koonda sufficiently

I used three different moulds for my vaults They were radiated to suit spans of 8, 15, and 22 feet I, however, discontinued those for the 8 feet span circular arc, as I made the vaults flatter To enable the workmen to readily distinguish the different kinds, I inserted small pieces of wood into the bottoms of the wooden voussoirs In this manner all the moulds are stamped, and, consequently, all the hollow voussoirs receive the same distinguishing mark Before commencing the mould making, the wooden voussoirs should be kept under water for two or three days, and afterwards they should never be allowed to dry, otherwise from increasing or diminishing in bulk, while they are being used, the moulds made with them will not be of the same size

To make the hollow voussoirs, the clay used should be what is commonly called "strong earth," or what is used for pottery It should be beaten into dust, and then mixed with dry horse-dung, also beaten to dust Water should then be added An hour or two afterwards, when the clay is completely saturated, it should be well mixed with the hand, sufficient water being added to make it of the consistency of paste or putty, so that it can be taken up in the hand and easily compressed into any form It should remain in this state for twenty-four hours, after which it is fit for use

The mould is filled in the same manner as the koonda A piece of clay, taken from that before-mentioned, is well worked up with the hands on a piece of plank, in the same way in which a native makes his bread,

It is then beaten out with the palm of the hand into two flat cakes, which are carefully placed against opposite sides of the mould, and overlapping each other a little The clay should then be well pressed into all the angles of the mould with the knuckles After this, a piece of clay, about the size of an apple, should be thrown smartly to the bottom of the mould If this is well done, it drives the clay previously placed most effectually into the acute angle at the bottom The pressure of the knuckles is not sufficient there, and, moreover this last piece of clay makes the circular wedge or mandrill (*Fig* 12) act more effectually The mould is then placed on the wheel, and a small chip of wood (*a*, *Fig* 12) an eighth of an inch thick, inserted between the clay and the lower side of the mould This is to prevent the wedge from making that side of the vousson too thin There is no necessity for a similar precaution for the other sides An iron rod like that previously mentioned, is then passed through the bottom of the mould into the top of the wheel Next a circular wedge or mandril (*Fig* 12) about half an inch less in diameter than the breadth of the mould, so as to leave round it about a quarter of an inch of clay for the thickness of the vousson, and having a hole bored through it for the rod, is placed in the mould, and plenty of water sprinkled on it The wheel, with the mould on it, is then set in motion with the foot, the wedge being thoroughly held with the hands and gently pressed downwards

If it descends very rapidly, it will be found on taking it out, that the cakes of clay are too thin, whenever this appears to be the case, more must be added with the hand If the wedge does not descend to the bottom, it is owing to there being too much clay, and this will have accumulated under it This should be removed, care being taken in doing so not to tear the sides of the vousson The hand should be conveniently placed against the clay, and the wheel set gently in motion The surplus clay is neatly cut off in this manner The wedge should then be again inserted, and the process continued, till the inside of the voussoir is perfectly smooth and free from flaws The wedge should be slowly removed from the mould, the wheel being kept in motion The wedge ought to go to the bottom of the mould This is ascertained by looking at the indentation made in the clay by the projecting piece, *b*, at the bottom, and which is made to prevent the wedge descending too far and destroying the bottom of the vousson It will be observed, from the manner in which the vousson has been made, that the acute angle at the bottom is solid This must be scooped out with the hand, and, at the

same time, the water which collects there during the process above described, should be removed with a piece of cloth

The next process is the closing of the mouth The surplus clay and chip of wood are first removed A good piece of clay tolerably stiff, is then rolled between the hands, until it is almost a foot long and an inch in diameter One end of this is attached to the mouth of the voussoir, and the wheel being set gently in motion, it is carried all round, and well joined to the voussoir, by pressing it and the side together with the thumb and the fingers This effected, the projecting clay is lightly held between the thumb and finger, and the wheel being kept in motion, the mouth is gradually closed If there is not sufficient clay, a small cake about the size of a rupee should be gently placed on the aperture, and the escape of the air inside immediately stopped by adding water, and joining the cake to the clay previously placed If this is not done quickly, the mouth will sink

The mould containing the voussoir may then be placed in the sun to dry, and when the clay begins to stiffen, the mouth must be hammered flat, a small hole being made to allow the air to escape In three or four hours the voussoir is sufficiently dry for removal from the mould, the mould being turned upside down, the voussoir drops out

In four or five days the voussoirs are dry enough for burning This is done in the same way as with common pottery A layer of dry sheep's dung is first laid on the ground, and over this a layer of light litter On this bed two layers of voussoirs are placed, and over the whole is another layer of litter, covered with ashes The ashes prevent the flame from escaping too soon

One coolie,* with two assistants to fill the mould for him, will, after a month's practice, make 70 voussoirs per day Allowing the first, in consideration of his skill,	Rs	0	2	6
And paying the assistants at the usual rate (viz, 2 annas each),	„	0	4	0
	We have Rs	0	6	6
for the cost of making 70, or say 10 annas per 100				
Again one buttee maker assisted by two coolies, will prepare a buttee containing 700 voussoirs in a day Allowing the buttee maker for his work, and for watching the buttee during the night,	Rs	0	5	0
Paying the assistants at the usual rate of two annas each,	„	0	4	0
And allowing one cart and a coolie 8 annas per day, for two days, for collecting litter,	Rs	1	0	0
	We have Rs	1	9	0

for the cost of burning 700, or say 4 annas per 100 Adding this to the cost of making, we have 14 annas for the cost of making and burning 100 voussoirs

* These were the prices in 1861

Until the coolies are expert, of course the voussoirs cost more than the above, but if the work is only cautiously commenced, and the number of hands gradually increased, the difference is not very great. I employed the carpenter, who made the wooden voussoirs, to superintend the mould making. I found this a good plan, as he readily detected flaws. I also employed a potter to show the coolies how to mix the clay and manipulate it on the wheel.

In order to employ convicts to make voussoirs for a Barrack for the Police, I used two wheels, on one the convicts made the voussoir in the rough, on the other the surplus clay was removed, and the mouth closed by a potter. The potter finished 150 voussoirs per day, with ease, in this manner. I, however, found, that from the voussoirs being frequently left standing in an unfinished state, they were not so well made, the clay becoming too stiff. By giving a man a wheel, and making him do the whole of the work himself, he can be held responsible for the quantity and quality of his work.

The first voussoirs I made had a hexagonal interior, as well as exterior, and were formed outside a mould, one of my reasons for preferring the hexagonal voussoir being, that of all regular figures which fit accurately together, the hexagon is that which has the greatest area compared to the perimeter, and is therefore the lightest form that can possibly be chosen. After a great many trials, however, I was obliged to relinquish this form for the interior, as the voussoir could not be made free from flaws. I also found that the weight was but little reduced by using the hexagonal interior, and the circular interior gave the voussoirs more substance and strength at the angles, which was an advantage.

It may appear from the preceding description that these voussoirs can only be made with clay of rare quality, but I feel sure, that wherever the clay is good enough for common pottery, (and there are few places where it is not,) they can be made equally well.

Construction of the Vault.—The haunches and end walls having been carried up to the requisite height, the first voussoir is let into the end wall at the crown of the curve, (*Fig* 17,) other voussoirs at proper intervals are then similarly let into the wall, till the haunches are reached. About one-half of each voussoir ought to project outside the wall, and the interval between each should be sufficiently large for the reception of half a voussoir and its cement. The vaulting is then commenced at the angles, which are gradually filled in, each course of voussoirs being com-

menced at the end wall, and carried obliquely down to the haunch in the following manner The sides of voussoirs 6 and 7, (*Fig* 17,) and the wall in front, being covered with cement, No 8 voussoir is thrust in (care being taken in doing so to keep the top parallel to the direction of the vault) with two or three blows from the hand It penetrates like a wedge, making the joints quite smooth After this, the joint should be closed above and below, to make them air-tight, till the clay has stiffened a little No 9 is then thrust into its place in the same way as No 8, forcing the latter, if it is possible, still tighter into its place This completed, No 10 in the next course is placed, and so on throughout the whole length of the vault

It will be observed, that by keeping the haunches of the vault advanced at this angle, any settlement at the crown is prevented Two sides of each voussoir being perpendicular to the direction of the course, they are directly opposed to any settlement The vault is kept in the proper curve by a circular piece of plank, standing on the projecting bricks of the cornice, and so little settlement takes place, that this can be made to slide back under the completed portion of the vault

The voussoirs run about 450 to 100 square feet, and a workman tolerably expert can vault 40 square feet in a day From the small number of voussoirs required, and the small quantity of cement used, he requires very little assistance

In all the vaults constructed on this plan, mud and bhoosa has been the cement used, and it has been found quite sufficient Being thrown against the voussoirs, and spread with the hand, it will be found more expeditious than chunam, and of course more economical

With regard to the haunches, it is evident that they should be carried up as far as ever they will stand securely without the assistance of the thrust from the vault, for the more the centre of gravity of the wall and haunch is brought inwards in this manner, the greater is the stability of the structure when completed I found from experiment that the haunches of a semicircular vault of 15 feet span could be carried up to a height of 5 feet To prevent accidents from a number of workpeople congregating on them before the vaulting was commenced, I carried the haunches up to a height of 4 feet in the first instance, completing them to the requisite height while the vaulting was being executed

J. F

No XLIII

DRAINAGE AND IRRIGATION OF THE TERRAIE

Abridged from a Report by CAPTAIN C S THOMASON, R E, *Superintendent of Terraie Irrigation*

A RECAPITULATION of the past history of the Terraie is unnecessary here Its progress within the last few years admits of no question, and no one now visiting this district, having in his hand the Report of Captain Jones, published in 1855, and referring to its state as far back as 1843, would venture to question this progress New tracts brought into cultivation, swamps drained, nullahs bridged, and straight communications established between the eastern and western extremities and elsewhere, in place of the tortuous cart-tracts of bygone days—all bear their own testimony to improvement, and the steadily-increasing influx of cultivators from the adjacent districts confirms this testimony, were confirmation necessary The Terraie, with its unlimited supply of water and large extent of virgin soil under an Indian sun, seems to possess every requisite for agricultural improvements The one drawback has been its climate, which, though doubtless improving to a considerable extent with the extension of cultivation, must still be reckoned one of the most deadly

The physical characteristics of the Terraie and the adjacent tracts have been so fully entered on in Captain Jones' Report, that I shall, only allude to them here as briefly as possible At the foot of the Himalayas, between them and Rohilcund, lies the tract of country known as "Bhabur" With some interruptions, the Bhabur tract lying north of Rohilcund extends from the Ganges to the Sardah Though its nature is in parts much modified, it has a slope varying from fifty to seventeen feet per mile, and may

be roughly defined as a forest tract with a subsoil more or less open. I shall in this Report restrict my observations entirely to those portions of the Bhabur which I have seen, and at present particularly to that portion of it to the north of the Terraie, between the Kylas and Kosee (or Kosilla) rivers. Its nature here is pretty uniform, and consists of a rather shallow but rich surface-soil, overlying a boulder-bed which gradually assumes the form of gravel as it approaches the Terraie to the south. In this boulder-bed the rivers issuing from the hills disappear when their discharges are small, as in the cold and hot seasons, but the water thus lost re-appears at lower latitudes in the form of springs. The greater portion re-appears in this form in the Terraie, but some streams have their origin even at more southern latitudes than this, thus leading to the conclusion that the soil underlying the boulders in the Bhabur is not a perfectly retentive one, and that possibly its nature may be alternately partially retentive and porous, the springs issuing to the surface wherever a more porous soil crops up. The beds of the hill streams are well defined across the Bhabur, but, except in the rains, the water in them disappears gradually as we leave the hills, and only re-appears as the Terraie is entered. The Terraie springs discharge into the beds of the hill rivers, so that the discharge of these rivers steadily increases as they progress southwards. The average breadth of the Bhabur between the Kosee and Kylas rivers is about ten miles, and the Terraie about the same. The average slope of the Terraie may be taken at a little more that ten feet per mile. The vegetation of the Terraie consists chiefly of jungle grass patches of forest exist, but the wood is not considered valuable for many purposes except fuel.

There seems to be good ground for supposing that, had the Terraie streams been allowed to flow uninterruptedly, few swamps would have been formed and consequently that the climate would never have assumed its present deadly character. But the temptations to irrigate with water within such easy reach were too great, and the evil effects of irrigation without drainage were then too little understood to deter cultivators from grasping at the enormous profits accruing from irrigation: hence the construction of earthen dams across the Terraie streams and rivers and the commencement of irrigation. The results of such a system in such hands are now apparent, and prominent amongst them may be noticed the formation of such swamps as the Cobra, and the diversion of streams from their original beds. The natural tendency of all such swamps is to gradually increase, and, as in

doing so they must to a greater or less extent saturate the adjacent soil, it is not difficult to account for the deadly nature of the Terraie climate

I shall now proceed to consider what measures the British Government has taken towards the drainage and irrigation of the Terraie, and the results of these measures

In the first place, many of the swamps have been penetrated by surface drains The Sissonah Swamp, formerly one of the largest in the Terraie, is now a swamp no more, many minor ones have been similarly got rid of, and before long we may reasonably expect to reckon the Cobra Swamp as a thing of the past So far, an indubitable benefit has been conferred upon the Terraie In many places the fevers which swept off their victims in the course of a few hours have now assumed the milder form of intermittent —a beneficial result, aided no doubt in a great measure by the clearance of jungle caused by the extension of cultivation

Irrigation, as a necessary concomitant of cultivation, has increased largely, and the Revenue Returns of the Terraie speak for themselves But an increase of revenue is by no means the sole object of Government, and, attended as it is with such a fearful loss of life, we may well pause to consider whether we are justified in thus enticing such numbers to a climate which, if not actually fatal, must undoubtedly produce a degeneracy in physique in succeeding generations.

Our present system of irrigation in the Terraie in principle differs in no respect from that formerly practised, which is universally acknowledged to be one of the chief sources of malaria It is in the supervision alone that we excel With such supervision the formation of such swamps as the Sissonah is impossible, but every earthen dam across a stream in such a soil as that of the Terraie must choke the pores of the adjacent soil with stagnant water, and such stagnancy must produce malaria

The question then arises—"How are these evils to be remedied?" There seems to me to be but one remedy open to us, and regarding the success of this we can but argue from analogy This remedy is the combination of *Sub-soil* Drainage with irrigation

Artificial Sub-soil Drainage is a practice almost unknown in India. Major Brownlow, R E (Supdt, Eastern Jumna Canals), mentioned to me the case of an experiment with sub-soil drained land in the vicinity of Meerut The experiment did not succeed, but the only cause of failure which I could learn was a deficiency of fall The general slope of the

country about Meerut is, I believe, about two feet per mile From what I can gather, there are few areas in Rohilcund where we cannot command a much greater slope than this, and in the Terraie there are few places where we cannot get ten feet per mile The efficacy of Sub-soil Drainage as a sanitary measure is undoubted in England, a very marked improvement being visible in the health and physique of the inhabitants of every district wherein it has been introduced

The absence of Sub-soil Drainage in India forms the subject of most frequent comment in the Report of the Sanitary Commission appointed to enquire into the state of the British Army in India It is there remarked, and with great justice, that all our efforts for the amelioration of the sanitary condition of our Cantonments must fall far short of success as long as Sub-soil Drainage in the fields is left to nature alone The remark, if I recollect rightly, was made without any reference to irrigation, but it must be evident that it applies with double force wherever irrigation is carried on My own impression is that well-regulated irrigation on thoroughly sub-soil drained land would be perfectly innocuous, whatever the crop might be

The main objections to the irrigation works which I have visited in the Terraie are—

1st *Inefficient Head Works*—The masonry regulators which have from time to time been constructed on the hill streams have been destroyed, and I have above alluded to the dangers and evils which are the results of the earthen dams which have been substituted for the masonry ones

2nd *Too great slopes of Canal beds*—The natural result of this has been retrogression of levels, which evil increases annually, to the great detriment of the irrigating capabilities of the canals A fair instance of this is seen in the Bygool Canal, the water in which, near the head, now stands many feet below the surface of the country, which formerly it used to irrigate The general slope adopted seems to be that of the country, the action on the canal beds can scarcely, therefore, fail to be the same as that on the beds of the rivers

3rd. *The formation of silt beds in the Canals* (naturally caused by their dependence during the rains on flood-water)—The removal of this silt entails a great annual expenditure and (as may be seen in the Western Jumna Canals) an annually increasing difficulty

4th *A want of method in the construction of the Irrigation Works* — The Terrai water-courses seem to be specially constructed to meet the wants of individual cultivators as they take up ground in the Terrai, consequently, as cultivation extends from the south to the north (up-hill) the length of water-channels must eventually be much greater than the necessities of irrigation demand The Terrai water-courses are, moreover, especially designed with a view to meet Terrai wants, these wants once satisfied, the surplus water is suffered to flow back into the drainage lines instead of being kept on the water-shed for the use of lower lying fields This system necessarily increases the number of dams, each of which is an evil in itself, independent of its expense

5th *The tendency to generate malaria*, which I have already noticed

6th *The clogging, and therefore inefficient irrigation of the soil*, owing to the want of aeration and warmth in the sub-soil arising from defective drainage

The comparative immunity from injury in dry seasons, enjoyed by thoroughly sub-soil drained lands is one well understood in England Sub-soil Drainage in its consequences is equivalent to an actual deepening of the soil and a change of climate, thereby ensuring an early as well as rich harvest

All these objections have received my serious consideration, and the system which I propose to adopt for their obviation will now be described

As a preliminary to all interference with the Terrai, I would strongly urge the necessity for a good contour-survey Without such a survey, whatever be the system finally determined upon, we cannot avoid many of the evils which now exist, and to which I have alluded above Such a survey is absolutely essential for the carrying out of any systematic drainage and irrigation scheme, without it, we must be working in a great measure, in the dark, with it, the design of efficient works is a comparatively easy matter

The following is an illustration of the system which I propose to adopt

Annexed is a sketch, *Plate* LV, representing an ideal tract of country such as we might expect to find at the foot of the hills Immediately south of the hills I have here represented as forest land what we may call the Bhabur It will be seen that three rivers are here represented as crossing the Bhabur These are hill streams, with which I do not think it necessary as yet to interfere.

The hill streams almost, if not entirely, lose their dry weather supply in the boulder-beds underlying the forest, and the supply thus lost re-appears in the form of springs, as at *a*, *a*, *a*, in the Terrai, and the districts south of the Terrai. From the points (*a*) the discharges of the springs revert to the hill streams, as shown in the plan. I suppose the centre District here represented to be divided into Divisions 1 and 2 by these hill streams, other Divisions lie east and west of these. For the more economical working of the system, owing to the peculiar lie of Division 1, is shown by the contour lines, I have sub-divided it into Sections 1 and 2.

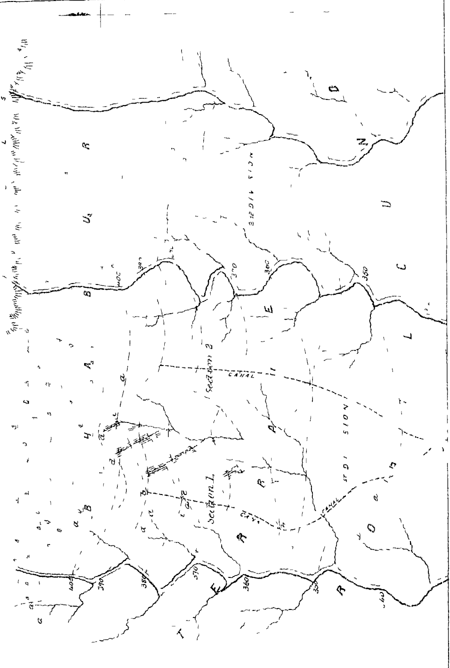
The most northern contour line is supposed to represent 400 feet above the sea according to the Great Trigonometrical Survey. The next contour line south of this represents a level of 390 feet, the next 380 feet, and so on—each successive contour line representing a drop of ten feet.

The canals are shown as following the salient points of the contour line, and thus are dug on the water-sheds of each section.

It is evident if a channel (say four feet deep) be dug from *b*, on the second contour line to *c*, on the first, that this channel will have a slope of ten feet. The channel from *b* to *c*, and the corresponding channel south of it, are "leader" drains: how far it may be necessary to have them open, and how far closed, local circumstances must determine; if probably they might be pipe-drains at the points furthest from the canal, and open as they approach the canals, discharging into the canal through a pipe. A similar drain is supposed to be constructed to the west of the canal, but, in order to render the plan more distinct, I have reserved the portion of the sections east of the canal for showing the drainage arrangements, and that west of the canal, for showing the irrigation. It must, however, be borne in mind that both drainage and irrigation exist on both sides of the canal, the latter overlying the former.

Where the eastern and western leader drains converge at *b*, is the commencement of the canal, which combines the purposes of drainage and irrigation, as will be shown hereafter. At *d*, *d*, I suppose springs to ooze out from the soil, and as I wish to keep the water of these springs clear of silt, I convey their supplies into the leaders as much as possible by sub-soil pipes: such pipe-drains I propose to call "feeders." I do not expect these feeders to convey away the whole produce of the springs in every case. They *may* do so, and, if so, an advantage will be gained; but if not, a provision will be made for catching the surplus water free of silt by a work to

DRAINAGE AND IRRIGATION OF THE TERRACE



REFERENCES

Hill Rivers	Leader Drains
Terrace Streams	Water courses for Irrigation (gools)
Feeder Drains (subsoil)	Contour lines (feet above sea)

which I shall allude presently Under any circumstances, a provision will have been made against the stagnation of water in the sub-soil, to which I have already alluded as one of the defects of the present system

If we now suppose the canal to be excavated with a slope of 2 feet for its bed up to the point *e*, on the next contour line of 380, it is evident that at this point the bed of the canal will be well above the surface of the country and in a position to irrigate east and west The bed would, in fact, be four feet above the level of the country at the point *e*, and if an irrigating channel (or "gool") were constructed from *e* to the western extremity of the 370 contour, the channel would have a slope of no less than fourteen feet from beginning to end

At the point (*c*) a fall of ten feet would be constructed, and, as I presume the water to be clear, a cheap form of fall might be constructed, as shown in longitudinal section in *Fig* 1, *Plate* LVI Instead of the usual masonry falls, I have here shown the southern extremity of the canal closed by an earthern dam, which might be made of sufficient thickness (if necessary) to serve as a road across the canal At a convenient distance to the north of this embankment, a pipe is shown descending from the bed of the canal at *a*, and merging into the lower bed with a trumpet-shaped delivery at *b* At (*a*) there would be a simple regulator (not shown) The object of the trumpet-shaped extremity to the pipe is to break the force of the water, the natural tendency of which would be to rise to its original level at (*a*) and cause erosion of the banks This idea is taken from the Edinburgh Water-works, where the precaution is rendered necessary as a guard against disturbance of the filter beds A gool (such as *e*, *f*) is shown in elevation issuing out of the canal at *c*, and a leader drain (similar to *c*, *b*) is also shown discharging into the canal at *d* The regulator (at *a*) would in principle be similar to a screw-top, a wooden plug being worked up or down by means of a screw, so as to open or shut the orifice of the pipe at pleasure This is a common form of regulator used in the mill-dams in Scotland, and is found to be very effective and cheap of construction

The main difficulty in such a work as that here described is in the pipe, which must be made capable of withstanding a considerable pressure, which an ordinary clay-pipe will not do, but I hope to overcome this difficulty by a system of concentric pipes of different diameters,—the interstices being run in with cement, asphalte, or some such substance We have, moreover,

fire-clay in the hills, and in England fire-clay pipes have been proved capable of withstanding a pressure of many feet

I will now proceed to show how I hope to avoid the silt difficulty I alluded to a particular form of work that would be necessary for this purpose in the management of the Terraie streams The principle of this work may perhaps be understood from reference to *Fig* 2, where the work is represented in longitudinal section The Terraie springs, in the cold and hot season run perfectly clear and free of silt, but in the rains, like all other streams, they become more or less muddy by reason of the soil washed into them by the rain water If the whole country could at once be thoroughly sub-soil drained with pipes, and divided oft into small kiarees with ridges, say four inches high, there would be no surface flow of water over the country, no abrasion of the earth's surface, and consequently no mud in the streams The rain-water would in this case fill all the kiarees up to a certain height, pass through the soil into the pipes, thus into the leaders, and eventually into the canal in a filtered state The Terraie streams would in such a case receive little or no accession of water in heavy rain But it is no part of this scheme to thoroughly sub-soil drain the whole of the land as works progress The first sub-soil drains must be those rendered necessary by swamps, such as must more or less exist where dams or other works interfere with the free flow of the streams, and the extension of the Sub-soil Drainage system must depend upon the extension of cultivation to render it remunerative The original bed of the stream is modified to the extent shown in *Fig* 2, by a fall say of ten feet The fall is, as far as the southern portion of it is concerned, an ordinary vertical one with a well, which experience has shown far excels the old ogee pattern At the lip of the fall it will be noticed that there is a peculiarity The top of the fall consists of a slab separated, except at bearing points, from the drop-wall Behind the drop-wall, at the top, is a masonry channel (a) supported on arches or by some other means Supposing the stream to be running south, this masonry channel (a) would be running east and west Its northern wall is perforated so as to allow sub-soil pipes (under the remodelled bed of the stream) to discharge into it As I have never seen this experiment tried, I cannot say how much water we might thus obtain from the sub-soil pipes The object of this feature in the work is to obtain a clear and filtered supply into the masonry channel (a) during heavy rains, when, from the construction of the

DRAINAGE AND IRRIGATION OF THE TERRAIE.

Fig 1

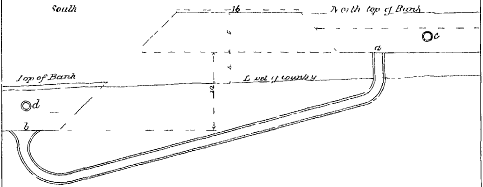


Fig 3

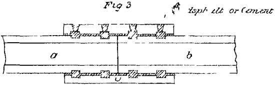
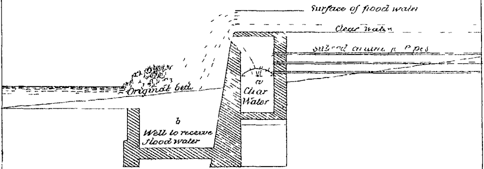


Fig 2



work, it would otherwise be empty At times when heavy rains are influencing the streams and charging them with silt, the water will over-shoot the channel (a) and discharge into the well (b), and thus proceed southwards, but in seasons when there is no silt, and consequently less water, if the length of the work be sufficient to lessen the velocity, it is evident that the water, falling gently over the edge of the slab, must be received into the channel (a) The efficient working of this plan depends upon the width of the slab and the length of the work I saw a work similar to the above forming a part of the Manchester system of Waterworks, where none of the water is ever filtered It had been constructed for some years, and gave perfect satisfaction The simplicity of the contrivance must, I think, strike every one

His Honor the Lieutenant-Governor, in the course of conversation, suggested to me that a difficulty might arise in carrying out Sub-soil Drainage in the Terrare owing to the numerous roots which abounded everywhere, and I ought not to omit allusion to this difficulty

When in Scotland, I was fortunate enough to make the acquaintance of Mr Murray, one of the Drainage Commissioners for Aberdeenshire, in which country the Sub-soil Drainage system has made most rapid progress within the last ten years Having obtained from Mr Murray much valuable information regarding the clearing out of sub-soil pipes when they become choked, I suggested the same difficulty as that now advanced by His Honor the Lieutenant-Governor In reply, Mr Murray remarked, that artificial Sub-soil Drainage was not adapted for forest lands, but that, where it was found necessary to cross a belt of trees, a method similar to that shown in longitudinal section in *Fig* 3, had, within the influence of roots, been adopted with great success Two drainage pipes, a and b, are here brought into contact, end to end, with a loose collar (c) covering the joint By a simple contrivance two annular shavings are taken of the exterior of each pipe a and b, previous to baking, and four corresponding annular shavings from the interior of the collar (c) Four holes (as shown here in section) are bored from the exterior of the collar (c) to each of the annular excisions In placing the pipes, a and b are brought together as here shown, with the collar (c) covering the joint Asphalte or some other cement is then poured into one of the holes of the collar so as to fill up the space between the collar and the pipes, care being of course taken to prevent the escape of the cement at the two extremities of the collar. The

cement must be thin enough to flow pretty freely so as to thoroughly fill the space between the collar and the pipes, and still not so thin as to run in between the two pipes, *a* and *b*. An air and water-tight joint is thus formed, effectually preventing the intrusion of roots. No asphalte, artificially made, has yet been found to equal the natural asphaltes of Seyssel, Trinidad, and elsewhere. In my estimate, therefore, I have made a provision for procuring a sufficient quantity for our more immediate wants. Further experience may probably suggest a more economical substitute.

I ought perhaps to mention that the slopes and other dimensions which have been here assumed for the different drainage and irrigation channels are purely arbitrary, and are simply adopted to illustrate the principal which I propose to follow.

A reference to *Plate* LV will show how this description of the works down to the point (*c*) is applicable to each "step" of the system in its progress downwards. It will be seen how the water is constantly being conveyed back to the water-shed after use, unavoidable waste being more than compensated for by constant recruiting from fresh springs in the progress of the system southwards. The canals of the two sections eventually unite (in *g*), so that the ravine dividing them is crossed at one point (*h*) alone, whereby considerable economy will be effected.

The chief difficulties in the execution of this scheme lie—

1*st*.—In the presence of water so close to the surface, which, though perhaps affecting the rates of channel excavation to some extent, would affect the rates of masonry foundation work still more so, rendering the work, in some instances, extremely difficult with the ordinary appliances at our disposal.

2*nd*.—The scarcity of workmen in the Terrai, where consequently we are obliged to give rates so very much in excess of what I have seen obtaining elsewhere.

3*rd*.—The glazing of the pipes, which very much improves them for some purposes, but which is as yet an impracticability in India.

The first two of these difficulties I propose to overcome by the use of machinery. The pipes for which we shall have such a demand must be made by machinery and the same machine, if furnished with the proper dies, might be of great use to us in many other ways, as, for instance, in the construction of light bridges and roofs, substituting hollow bricks and pipes for the quickly-decaying timber, the use of which is now so universal

in the Terrae The third difficulty of glazing I propose to overcome temporarily by the substitution of Ransome's process, of which I have had some personal experience The results obtained by Ransome's process are very satisfactory, though the process itself is not so economical as the ordinary process of glazing practised in England When our works are fairly started, and our kilns in good working order, I anticipate little difficulty in introducing the art of glazing with common salt and other substances

The portion of the Terrae which to me seems best adapted for commencing operations, is that lying between the Kylas and Sookhee rivers The tract here is narrow, the cultivation extends up to very near the Bhabur, the present irrigation works there are very troublesome to maintain, and the population perhaps greater than in most other parts The health of this population must be very injuriously affected by the proximity of the Mahadeo Swamp, which, though much silted up, is still undrained The Sissonah Swamp, though surface-drained, would most probably benefit greatly by the addition of sub-soil drains Moreover it would no doubt add very greatly to the sanitary condition of the tract of country surrounding Sittargunj, if the Kilpoorie forest were opened up more, thus permitting of a more free circulation of air The timber of the forest would afford us an unlimited supply of fuel for the steam-engine, which I look to as our great auxiliary The Sookhee, though forming the western boundary of our first division, would not be the limit of our first operations, as, to form a just idea of their value in a sanitary point of view, I think the removal of the neighbouring swamps on its western bank would be essential I should therefore, to the west of the Sookhee, confine myself in the first place, chiefly to drainage operations, keeping irrigation in view as a future contingency, and between the Sookhee and the Kylas carry on drainage and irrigation simultaneously

I feel how incomplete this present Report must be without an Estimate of the probable cost of Sub-soil Drainage in the Terrae It is with extreme diffidence that I approach this subject, for, in the first place, never having carried on any work in the Terrae, I can form only a very vague idea of the rates which obtain there The pipes (which form so essential a part of the scheme) have never, to my knowledge, been made by machinery in India, and even if they had, the rates for Terrae labor seem to me to be so exceptionable, that the rates of other districts, even

if available, would hardly be any guide Moreover, all such questions as these must resolve themselves into one of remunerative value, which again must depend in a great measure upon the market-value of the land upon which we propose to operate

I think it, therefore, fair to myself to place before Government the data upon which I base my calculations My wish is to over-estimate rather than under-estimate, and if the cost of our first operations should exceed my expectations, I trust that due allowance will be made for my scanty means of obtaining information Many—and amongst them officers whose experience entitles them to consideration—consider that we are not yet sufficiently advanced for the introduction of Sub-soil drainage I have been frequently told that it will not pay, but as I have never yet had presented to me any substantial grounds for the supposition, or the ground-work of the calculations upon which this opinion has been formed, I must beg to be allowed to retain my present conviction that it will pay, till results have proved to the contrary The main objection, as I have already stated, is the expense, let us therefore consider, with the data at our disposal, what this expense is likely to be

First, as to the pipes No one has yet ventured to tell me what these are likely to cost, and it is rather an important part of the calculation At Roorkee I had some experience in constructing Syrian roofs These roofs are arched, the voussoirs of the arch consisting of baked earthen bottles, ten inches long, five inches diameter at the bases, and slightly tapering towards the necks, which latter form the intrados of the arch Every bottle (made by the potter) was turned by the hand, and must have been the result of a considerable amount of labor it was baked in the rudest native kiln at a great expenditure of fuel, and fuel at Roorkee has to be carted from some distance This is the nearest approach to the average-sized drain-pipe for which I can furnish a rate The bottles were supplied to me on the spot, after a carriage of more than a mile, at the rate of ten rupees a thousand, and for this rate I was allowed to reject all unsound or under-burnt ones I never had any difficulty in procuring any number at this rate, so I am sure it paid the manufacturer well The drainage pipes which I propose to make for the Terraie will be made in a machine, which will turn out, I suppose, fifty pipes to one bottle made by the potter The kiln I propose to use will be of the most approved English pattern, admitting of drying and manufacture at all

seasons, the fuel is on the spot, and in the first place my labor will be furnished by steam-engine, most likely to be supplanted, as our works progress, by a still more economical motive power—water. Under such circumstances, I assume that my drainage pipes will not cost more than *five* rupees a thousand, which is one-half the English price. Adding, say one rupee a thousand for carriage, &c., they will cost *six* rupees a thousand when laid.

The next item for consideration is the cost of excavation. The rate for excavation I will take as that given me by Mr. E. Colvin, high as that is, viz., *two* rupees *eight* annas per thousand cubic feet. For similar excavation I have repeatedly paid less than one rupee per thousand cubic feet on the Ganges Canal, and, should we extend our operations and import labor, I have little doubt that we shall succeed in reducing Terraie rates to something like a par with those of other districts, and as the progress of our works renders the Terraie more healthy and habitable, our difficulties in the matter of rates will be still more favorably affected. However, we must start at least with prevailing rates, and as anticipation on my part might be objected to, I have adopted these rates in my Estimate, adding one-half as much again for refilling after the pipes have been laid. The rates for excavating and refilling are therefore placed at *three* rupees *twelve* annas per thousand cubic feet.

The following Table will then show the estimated cost of a few likely cases of Sub-soil drainage per acre:—

1	2	3	4	5	6	7			8			9		
No. of Case	Depth of Drain	Width of excavation at top	Width of excavation at bottom	Distance of Drain apart	Length of Drain in feet	Cost of excavation and refilling per acre			Cost of Pipes per acre.			Total cost of sub-soil drainage per acre		
						R.	A.	P.	R.	A.	P.	R.	A.	P.
1	3 feet	15 inches	3 inches	18 feet	2,421	20	6	10	14	8	5	34	15	3
2	,,	,,	,,	24 ,,	1,815	15	4	10	10	14	3	26	3	1
3	3½ ,,	21 ,,	,,	24 ,,	1,815	23	13	1	10	14	3	34	11	4
4	4 ,,	,,	,,	,,	1,815	27	3	7	10	14	3	38	1	10
5	,,	,,	,,	33 ,,	1,320	19	12	10	7	14	9	28	5	7

From the above Table, I should fix about *thirty* rupees as the average

cost per acre of Sub-soil drainage in the Terrai. The dimensions of the sectional area of the drains are taken from English examples.

Thus far I have assumed that the drainage is to be carried on by excavators in the usual manner practised in England; but, if I am not mistaken, the Terrai land is just one of those peculiarly adapted for the application of the drainage plough, as invented some years back by Messrs Fowler and Fry of Bristol. This machine, in soils adapted for its use, is admitted to lay pipes better than they can be laid by hand, and the estimated cost of drainage by its means in England is calculated at three-fifths of that without it. Of course, as it is not adapted for all conditions, such as stony and hilly ground, we cannot calculate upon its assistance everywhere; but it is peculiarly adapted for swampy soil, free from stones, and generally level, and it is just such cases as these with which we shall have first to deal. That there are cases even in the Terrai where this useful machine cannot be employed I do not doubt, but I believe that such cases will prove to be comparatively few, and, given steam-power to work it, I do not see why we should not derive as much benefit from the use of this machine here as in the flat alluvial counties of England. Should my anticipation be well-founded and the draining plough come into universal use, considering that we should thus be rendered independent of the exorbitant Terrai rates for labor, I see no reason why our average cost for sub-soil drainage should exceed, if it attains, *twenty* rupees per acre.

I will now proceed to take into consideration the general question—"Will Sub-soil Drainage pay in the Terrai?" An English farmer, in placing such a question before himself, would naturally first consider the annual revenue derived from his undrained land. If he were to follow the opinions of such authorities as Donaldson, Johnston, Mechi, and others, he would probably reckon upon one-half more out-turn from his land when drained than before, and the calculation of how long it would thus take him to recover the money spent on drainage works would not be a very difficult one. If swamp were the only evil of which he could complain, and his land were otherwise good and well-farmed, he would probably find the whole of his money returned to him with interest in one year, as I myself and many others have done; but if his soil and other circumstances were such as we commonly find, and he farmed only moderately well, he could scarcely fail to recover the whole of his money in three years, which is no bad rate of interest even for India.

I have tiied fiequently to aiiive at some aveiage value foi land in the Teiiaie, but I am soiiy to say that I can get at nothing moie definite than that its paid ievenue to Goveinment vaiies fiom two annas to one rupee fouiteen annas pei beegah, oi (if we ioughly adopt English measuies), fiom about thiiteen annas to thiiteen iupees pei acie The soils upon which I piopose fiist to opeiate might almost be consideied valueless in theii piesent conditions, and as, when diained, I think it might fairly be consideied woith ten iupees an acie at least, it is evident that, at this iate, even Goveinment would iecovei the money in thiee years The piofit to the tenant would ceitainly not be less than that acciuing to Goveinment

---

ESTIMATE OF EXPENDITURE FOR THE FIRST YEAR

		£	S	D	R	A	P
Survey Establishment,					5,000	0	0
MACHINERY	Ten hoise-powei Steam Engine	600	0	0			
	Pumps, &c,	200	0	0			
	Machines foi making Biicks, Pipes, &c,	600	0	0			
	Moitai mills foi giinding Cement,	100	0	0			
	Sawing Machines,	50	0	0			
	Lathe tor Woikshop,	50	0	0			
	Asphalte and Caldiion,	50	0	0			
	Ransome's Silicate of Soda and Chloiide of Calcium,	50	0	0			
	Caiiiage,	300	0	0			
	Total,	£2,000	0	0	20,000	0	0

WORKING EXPENSES

	R	A	P
Foi building Kilns, manufactuiing Biicks, Pipes, &c,	5,000	0	0
Total Rupees,	30,000	0	0

NYNEE TAL,
May, 1864

C. S THOMASON.

No XLIV

DIMENSIONS OF ARCHED BRIDGES

The following Formulæ, for calculating dimensions of Bridges are taken from a French Manual of Civil Engineering (Formules, tables et renseignements pratiques, Aide Memoire des Ingenieurs, Architectes, &c PAR J C CLAUDEL, *Paris,* 1860) N B —*The Constants have been converted to suit English feet*

I —THICKNESS OF ARCH AT CROWN

e Thickness of Arch at Crown

d Span

$$e = \frac{d}{30} + 1\ 1$$

II —THICKNESS OF ABUTMENTS

e Thickness of Arch at Crown

d Span

h Height of Abutment from Spring to Foundation surface

f Versed-sine or Rise of Arch

E Thickness of Abutment

H Height from Foundation to the top of the Extrados as loaded. For road bridges the surface of the loaded extrados may be assumed to be 2 feet above the crown of the extrados of the arch, and $H = h + f + e + 2$

1 —FOR SEGMENTAL ARCHES

$$E = (1 + 212\ d)\sqrt{\frac{h}{H} \times \frac{d}{f+e}}$$

2.—FOR SEMICIRCULAR ARCHES

$$E = (2 + .162\, d)\sqrt{\frac{h + \frac{1}{4} d}{H} \times \frac{0.87\, d}{\frac{1}{4} d + e}}$$

3.—FOR ELLIPTICAL ARCHES

$$E = (1.4 + .154\, d)\sqrt{\frac{h + .54 f}{H} \times \frac{0.84\, d}{.46 f + e}}$$

These Formulæ are based on the following assumptions:—1*st*, That in Segmental arches the joint of rupture will be at the springing; 2*nd*, That in Semicircular arches having a horizontal extrados the joint of rupture will be at an angle of 60° with the vertical, or $\frac{1}{4} d$ above the springing. This leaves the span between the points of rupture .87 d; 3*rd*, That in Elliptical arches the joint of rupture will form an angle of 45° with the vertical, and will be at a height of .54 f above the springing. Also that the span between the points of rupture will be .84 d.

The numerator of the fraction having H for its denominator is the height from the foundation to the point of rupture.

The numerator of the second fraction is the span between the points of rupture; the denominator, the distance from the point of rupture to the extrados of the arch. It is understood that the thickness of abutment calculated from the formulæ is the *mean* thickness, which in practice may be obtained when so desired by the help of counterforts, the wing walls being reckoned as such when suitably placed.

There is one objection to the first of the above formulæ, viz., that the depth of Keystone is made independent of the Radius of Curvature at the crown.

Professor Rankine has given the following empirical rule founded on dimensions of good existing examples of bridges.—

For the Depth of the Keystone, take a mean proportional between the Radius of Curvature of the Intrados at the Crown, and a constant, whose values are,

for a single arch, ..	.12 foot,
for an arch forming one of a series, .	.27 „

That is to say,

For a single arch, $e = \sqrt{.12\, r}$

For an arch of a series, $e = \sqrt{.17\, r}$

THE ANNEXED TABLE SHOWS THE COMPARISON BETWEEN THE DIMENSIONS CALCULATED BY THESE FORMULÆ AND ACTUAL BRIDGES

	Bridges	Span	Versed sine	Height of abutment	Thickness at Crown: Real	Thickness at Crown: Calculated by French formulæ	Thickness at Crown: Calculated by Rankine's formulæ	Total height	Thickness of Abutment: Real	Thickness of Abutment: Calculated by French formulæ	Radius of curvature at crown	Remarks
		d	f	h	e	e'	e''	H	E	E'	r	
	I SEGMENTAL ARCHES											
1		13.1	2.3	13.1	1.8	1.5	1.3	18.9	5.9	5.8	10.45	
2		16.4	2.6	6.6	1.7	1.7	1.6	12.9	5.6	6.3	14.2	
3		25.0	2.9	14.1	2.1	1.9	2.1	20.9	11.7	11.8	28.3	
4		37.4	4.9	11.6	2.0	2.3	2.0	20.8	17.1	15.2	37.8	
5	Various bridges in France and England,	42.7	6.1	6.6	3.0	2.5	2.6	17.2	17.1	13.9	40.4	
6		46.0	6.2	20.4	3.6	2.6	3.1	31.2	19.0	19.9	45.7	
7		52.7	5.1	12.9	3.0	2.9	3.4	22.9	32.8	23.4	70.1	
8		53.5	10.2	20.7	2.8	2.9	2.6	35.8	16.0	19.0	40.1	
9		76.8	6.4	27.7	4.8	3.7	4.5	39.8	38.7	39.7	118.4	
10		82.4	11.7	17.8	4.6	3.9	3.6	35.4	31.5	30.1	78.4	
11		86.5	13.5	16.6	3.5	4.0	3.6	36.1	32.0	29.2	76.0	
12	Bridge at Turin,	147.6	18.0		4.9	6.02	4.38				160.0	Single arch
13	Grosvenor bridge over the Dee,	200.0	42.0		4.0	7.8	4.1				140.0	Ditto
14	Bridge of St. Maxence,	76.7	6.4		4.79	3.6	4.49				119.0	
15	Dean bridge,	90.0	30.0	..	3.00	4.1	2.88				48.75	

II Semicircular Arches.

1	Various bridges,	2.0	1.0	3.0	1.1	1.2	0.41	7.2	1.6	1.7	1.0
2		6.6	3.3	7.9	1.1	1.3	0.75	14.5	3.9	3.4	3.3
3		6.6	3.3	6.4	1.6	1.3	0.75	13.0	3.3	3.3	3.3
4		9.8	4.9	11.8	1.3	1.4	1.3	20.1	4.6	4.5	4.9
5		13.1	6.5	13.1	1.6	1.5	1.5	23.2	4.9	5.3	6.5
6		16.4	8.2	9.8	1.8	1.7	1.7	21.7	5.9	6.1	8.2
7		24.3	12.1	6.6	2.0	1.9	2.0	22.7	6.9	7.2	12.1
8		26.9	13.4	11.8	2.5	2.0	2.1	29.3	10.5	8.3	13.4
9		37.1	18.5	20.7	3.9	2.4	2.5	43.7	9.8	11.0	18.5
10		49.2	24.6	6.6	3.9	2.7	2.9	35.9	12.5	12.2	24.6
11		65.6	32.8	3.3		3.3	3.3	41.4	14.8	14.7	32.8
12	Ballockmyle Bridge,	181.0	90.5		4.5	7.13	3.92				90.5

III Elliptical Arches

1	Various bridges,	19.7	7.5	1.3	2.0	1.8		12.6	5.3	5.1	unknown
2		39.4	14.8	10.2	3.0	2.4		29.4	12.3	11.1	
3		51.1	17.1	13.6	3.7	2.8		35.5	14.9	14.9	
4		52.2	17.4	1.3	3.7	2.8		23.5	11.8	12.8	
5		70.0	17.5	12.0	2.3	3.4		34.9	16.5	21.6	
6		79.4	26.2	2.9	3.9	3.7		34.8	18.4	19.6	
7		80.4	27.7	6.4	4.5	3.8		39.9	19.2	20.4	
8		115.2	34.4	3.2	6.4	4.9		44.5	28.8	28.9	
9		127.9	32.0	7.5	5.3	5.4		46.9	35.4	35.6	
10	Blackfriars centre arch,	100.0	40.0		6.7	4.43					
11	Ganges Canal bridges,	55.0	12.0	8.0	3.0	2.93	2.5	24.93	13.3	17.5	37.5
12		50.0	7.0	8.0	2.25	2.77	2.8	19.77	11.3	18.6	48.1
13		45.0	6.0	8.0	2.5	2.6	2.8	18.6	13.6	17.2	45.2
14		40.0	5.4	9.0	2.0	2.43	2.6	18.83	11.0	15.75	39.7
15		35.0	4.5	9.0	2.5	2.27	2.5	17.77	10.3	14.2	36.27
16		30.0	4.0	9.0	2.25	2.1	2.3	17.1	6.25	12.3	30.1
17		25.0	4.0	9.0	2.0	1.93	1.9	16.93		10.1	21.6
18		20.0	2.67	9.0	1.5	1.77	1.9	15.43		8.7	20.6
19	Markunda,	36.5	9.0	12.0	2.5	2.32	2.0	25.57	16.5	12.41	23.0
20	Sohan,	63.0	16.0	24.0	3.0	3.2	2.9	45.2	15.0	15.13	48.0

	Bridges	Span	Versed sine	Height of abutment	Thickness at Crown: Real	Thickness at Crown: Calculated by French formulæ	Thickness at Crown: Calculated by Rankine's formulæ	Total height	Thickness of Abutment: Real	Thickness of Abutment: Calculated by French formulæ	Radius of curvature at crown	Remarks
		d	f	h	e	e'	e''	H	E	E'	r	
	III. Elliptical Arches (*Continued*)											
21	Bridge over the Severn,	150 0	35 0		4 5	6 1	4 39				160 7	Single arch
22	Ordinary bridge over double line of Railway,	30 0	7 6		1 83 to 2 0	2 1	1 9				30 0	Ditto
23	London bridge,	152 0			5 0	6 2	5 25				162 0	
24	Waterloo bridge,	120 0	32 0		5 0	5 1	4 37				112 5	

No XLV

MARKUNDA BRIDGE

Specification and Estimate of the Bridge over the Markunda River, near Umballa, now being constructed by W PURDON, ESQ, C E, *Exec Engineer*

THE whole of that portion of the plains which lies between the Sutlej and Jumna, is drained by three great rivers and their tributaries These are the Guggur, the Tangree, and the Markunda, each of these rivers has its source within one of the outer ravines of the Himalyas, which rise above the plain to the east

The Markunda river drains the largest area, and is in other respects also the most formidable of the three It rises at an elevation of between four and five thousand feet above the sea, draining the heights of Tytok and Nahun, names familiar during the Goorka war of 1814, after a course of about 15 miles within the hills, it enters the plains near Kala-Am, 8 miles lower down it is joined by the Roon, a nuddee, which has its course in the higher hills, and which adds almost as large a body of water as the main stream, 7 miles further, the Khur iki nuddee joins it, and a little below Moulana, 11 miles further, the Beguna adds a very considerable body of water—the drainage of the plain which lies between the Markunda and the Tangree rivers, 12 miles below the junction of the Beguna The Grand Trunk road crosses 35 miles further on, and a little above Pehowah the Sursootee river joins, beyond this the united stream takes the name of the tributary The Sursootee is much inferior in size, having its source in the plains, not more than 50 miles above its junction with the Markunda, about 25 miles below Pehowah, the united stream joins the Guggur, and is lost with that river in the plain of Rajpootanah

The whole length of the Markunda is 113 miles, its course through the plains about 98 miles, and its general direction, E S E

Its course through the higher hills has not been examined Through the plains its belt of variation is, on the whole, well defined, varying in width from $\frac{1}{4}$ to $\frac{3}{4}$ of a mile, and from 4 to 8 feet in depth This description holds good to about Hussunpore, a village about 3 miles above where the Grand Trunk Road crosses the river , below the village, and almost to the junction with the Surssootee, the banks are ill defined, the river is not self-contained, but overflows its banks, flooding the country for several miles Having its sources in the higher hills, the rise of the Markunda is exceedingly rapid, and even where it crosses the Grand Trunk Road, it retains all the characteristics of a mountain torrent, rapid and violent , pebbles and course gravel are carried down nearly as far as Moulāna, about 25 miles below the hills Near Kala-Am, where it first issues from the hills, some of its water is led off for irrigation, but a good deal escapes away down the loose rocky bed of the river, and even where the Grand Trunk Road crosses the river, an insignificant stream may be observed up to April, doubtless fed in part by springs in the bed of the river itself

During the floods of the rainy season, the river has a depth of 6 to 9 feet It offers considerable obstruction to the traffic which passes over the Grand Trunk Road, travellers being frequently delayed for many hours , even after the floods have subsided, the crossing is not unattended with risk, owing to the frequent quicksands in the bed

From the observations and surveys made by Mr Campbell, C E , in 1859, he obtained the following discharge in the river during flood The observations were made near the village of Hussunpore, about 3 miles above the site of the bridge, where the banks of the river are well defined

Width of channel, - - - -	1,577 feet
Area, - - - - -	6,938 „
Rate of fall, - - - - -	3 72 inches per minute
Mean velocity, - - - -	5 15 „ per second
Discharge, - - - - -	35,730 cubic feet

Mr Campbell's investigations further ascertained that in 1845, a flood rose 18 inches above the bank of the river on which Hussunpore stands, giving a discharge of 47,838 cubic feet , nothing approaching to this has occurred since

A design for a Bridge for this river was prepared in 1856, by Cap-

tain Grindall, at an estimated cost of Rs 5,13,646, and the work was actually commenced

In 1860, Mr Campbell submitted four alternative designs, embracing a brick bridge of arches of 80 feet span, two designs for a wire suspension bridge, and a cast-iron girder bridge of 30 feet spans, on screw tubular piles

The Government of India, while acknowledging the care and labor expended on the subject by Mr Campbell, preferred a modification of the original design to any of them, and gave the following specific instructions for the preparation of the new design

The width of the Roadway to be reduced to 26 feet, the depth of the Pier Foundations to be limited to 15 feet, and that of the Curtains to 12 feet

The bridge to be divided into five sections by Abutment Piers

The Water-way not to exceed 1,073 running feet

In compliance with the above instructions the accompanying design has been prepared

The portion of the block foundations which had been partly sunk by Captain Grindall have been made use of.

The drawings are so fully detailed, that it is believed every necessary information may be obtained from them

The estimated cost of the bridge is Rs 3,61,180 The whole of the piers, abutments, and wings are now (July, 1864) brought up to the level of the imposts The turning of the arches (27 in number) will be commenced after the floods have subsided

The nature of the Foundations of the bed of the river was examined by both Captain Grindall and Mr Campbell, but nothing but sand, or at best, a clayey silt, was met with, to a depth of 10 feet

The total length of the bridge is 1,400 feet, the height of the roadway above the bed of the river is 24 feet, and the width of the road 26 feet

---

Specification

The Curbs for the wells to be made of Keekur, Tallee, Jamun, or other sound jungle wood, approved of by the Executive Engineer, they will be 9 inches in thickness, put together in threes, and firmly secured together by wooden treenails of seasoned Keekur wood The masonry walls of

the Wells are to be 9 inches in thickness, and are to be built of radiated bricks, moulded or cut to the proper form, and laid with mortar composed of two parts of soorkhee, to one part of freshly slaked stone lime, burned on the works, and well mixed together in a mortar mill in the usual manner.

All Bricks used in the work are to be soaked for at least six hours previous to their being used, and the masonry is to be kept moist, to prevent the too rapid desiccation of the mortar, until the mortar gives indications of setting. The walls of the wells are to be carried up six feet, and allowed to dry for at least ten days, when the undersinking may be commenced.

The whole of the wells of one Pier or Abutment, are to be undersunk together, when the wells have been sunk 3 or 4 feet, then the walls may be raised 6 feet more, when the wells have been sunk 8 feet, then the walls must be weighted with kucha pucka masonry, to facilitate the undersinking, as well as to prevent the walls parting from the curbs.

When the wells for the Curtain Walls have been sunk to their full depth, the excavation for the Concrete, which is to be laid between the wells of the piers, (as shown on the drawing,) as well as for the concrete beneath the flooring, is to be commenced.

As soon as a well has been sunk to the required depth, it is to be filled at once with broken brick to the required level. In laying the concrete, 6 inches is to be laid and consolidated at a time, water from the foundation having been removed by pumping.

In Undersinking the Wells, the old system of *jhams* and divers will be dispensed with as much as possible, pumps will be used to keep down the water in the well, and ordinary excavators will be employed, the material being brought up by means of a bucket and windlass, when the material at the bottom of the well is slush, the bucket is to have a valve in its bottom so as to fill itself.

In the Piers and Abutments, the bricks will be laid in English bond, with half-inch joints, and grouted every course.

As the work advances, the hardest and best shaped bricks will be set aside for the Arches. Each Arch will be divided into several portions, by joints running completely through from soffit to back, the bricks being laid in these successive portions, alternately in rings and blocks with joints running entirely through the arch, from soffit to the back.

English bond will be used in the portion laid in rings, the thickness of the arch being divided into two equal rings, the blocks in which the joints run through, are not to exceed four bricks in thickness, measured on the soffit. Great care will be taken in laying the bricks which form the Keys of the Arches, thin tempered mortar or grout being used, and the joints well wedged up with hard pieces of brick, in keying in the arch, the first course on the soffit will be formed of a thickness of three bricks laid on their ends, in very thin mortar, the next course will be formed of five bricks, laid also on end, and forming continuous joints with those below them, this course will be laid in grout. By dividing the length of the course into several compartments, separated by a single row of bricks, laid in mortar, the grout may be poured into these compartments, and the bricks be set in it, and the joints then filled with pieces of brick.

The haunches of the arches will be carried up and allowed to set before bringing up the remainder of the arch. Care must be taken to load the crowns of the centres to prevent springing.

The arches will be turned on regularly framed timber Centres, these will be supported by timber struts, each point of support will be capped by a strong wooden pillar plate, on this will stand a cast-iron cylinder fitted with a wooden piston. The cylinder will be 9 inches in diameter, of sheet iron, in thickness $\frac{3}{16}$-inch and 12 inches in length, open at both ends. It will have four half-inch holes, at half-an-inch from the lower end of the cylinder, these holes will be fitted with four wooden plugs so that they may be pulled out and inserted by the hand, each cylinder will have a solid wooden piston fitting it freely, and of the same length as the cylinder, the cylinders will be filled to $3\frac{1}{4}$ inches of their length with clean sand, on which the wooden piston will rest. When it is desired to strike the centering, a man will be stationed at each cylinder, at the order being given, they will simultaneously pull out every man his four plugs, the sand will be allowed to run out until it forms a sort of semicone on the pillar plate opposite each hole, when the sand will stop running until the sand outside be cleared away, on which, it will run again from the cylinder, and so on, care must be taken that no moisture finds its way down the sides of the pistons at the cylinder.

The centres will be slightly eased immediately after keying the arch, but the centres are not to be struck until six weeks at least have elapsed after the keying in, a longer time will be allowed if convenient.

The Mortar to be used on the work is to consist of one part of freshly burnt stone lime, and two parts soorkhee, made from pieces of pucka bricks, and ground in a mortar mill in the usual manner, that used for the face joints to be ground in a hand mill

The Concrete will consist of the following proportions —

1 part of stone lime

3 parts of soorkhee from pucka bricks

6 parts of broken bricks, kunkur or stone, two-thirds of which not to be larger than a hen's egg

The concrete to be mixed together in a little tank close to the work and thrown in from a height, no plaster will be used on any portion of the work

ABSTRACT OF ESTIMATE

		R	A	P
c ft				
2,011,294	Excavation in foundations, including cost of pumping, baling, &c, at Rs 8 8 per 1000,	17,095	15	11
865	Neemchucks, complete, at Rs 14 each,	12,110	0	0
l ft				
12,154	Well sinking (including kucha masonry) to 15 feet below zero of gauge, at Rs 2 7,	29,625	6	0
c ft				
326,191	Masonry in foundations, wells, curtain walls, and flooring, at Rs 25 per 100,	81,547	12	0
307,943	Masonry in superstructure, parapets, wings, revetments, and barrelled drain, at Rs 22 per 100,	67,747	7	4
203,747	Masonry in arching and inverts, parapets, cornice, coping, towers, and roofing of do, including ornaments, and cost of centres and scaffolding, at Rs 35 per 100,	71,311	7	2
243,223	Concrete in foundations, revetments, barrel drain, &c, including cost of pumping, at Rs 13 per 100,	31,618	15	10
53,649	Metalling, at Rs 14 per average 100,	7,510	13	9
1,564,968	Earth rammed between wing walls, &c, and in embankment north east flanks of the bridge, and in excavations to put in centerings, at Rs 2-8 per 1000,	3,912	4	5
r ft				
2,896	Stone curbs to roadway, at Rs 2,	5,792	0	0
50	Piles, including driving each,	50	0	0
200	Fascines, at Rs 12 per 100,	24	0	0
	Preliminary operations, including godowns, workmen's sheds, lime kilns, plant, contingent losses by flood, and cost of native supervision at 10 per cent,	32,834	10	4
	Total Rupees,	3,61,180	12	9

W PURDON, C E

No XLVI

NOTES ON RETAINING WALLS

(2ND ARTICLE)

BY "DHARWAR"

SIMILAR to the above table for banks with horizontal surfaces, is the following for surcharged banks, that is, banks where the surface slopes up from the top of the wall For the maximum case of this when the surface slope equals the natural slope of the material, the formula is $P = \frac{W h^2}{2} \cos^2 \theta$, and the breadth of a vertical rectangular wall, $b = h\ 578 \cos \theta \sqrt{\frac{W}{W_1}}$

The co-efficients of h (K in the table) therefore $= 578 \cos \theta \sqrt{\frac{W}{W_1}}$, and $b = K h$

b, the breadth here obtained is also that theoretically required for bare equilibrium

Of the elements of stability not considered in the formula, that due to the friction of the earth against the back of the wall is the most considerable

Supposing the co-efficient of this friction to be at least equal to that of earth on earth, we have the value of the force of friction $F = P \tan \theta$, and its moment $= b\ P \tan \theta$.

The value of $\tan \theta^\circ$ will range between the limits 1 to 6, so that $F = P$, or $6\ P$. This element of stability is therefore one of very considerable value

TABLE OF CO-EFFICIENTS OF h FOR BREADTHS OF VERTICAL RECTANGULAR WALLS $b = \mathrm{K}\,h$

Top of Bank Sloping up at Natural Slope from Top of Wall

Ratios $\frac{W}{W_1}$	Fracts	$\frac{1}{1}$	$\frac{1}{1\cdot1}$	$\frac{1}{1\cdot2}$	$\frac{1}{1\cdot3}$	$\frac{1}{1\cdot4}$	$\frac{1}{1\cdot5}$	$\frac{1}{1\cdot6}$	$\frac{1}{1\cdot7}$	$\frac{1}{1\cdot8}$	$\frac{1}{1\cdot9}$	$\frac{1}{2}$	$\frac{1}{2\cdot1}$	$\frac{1}{2\cdot2}$	$\frac{1}{2\cdot3}$	$\frac{1}{2\cdot4}$	$\frac{1}{2\cdot5}$	Values of cos $\theta°$ or sin ϕ
	Decs	1	909	833	769	714	666	625	588	555	526	5	476	455	435	416	4	
Angles of Repose $\theta°$	K, K, &c, for the above ratios																	
30°	K, K, &c for the above angles	500	476	456	438	423	409	395	384	372	363	353	345	337	33	323	316	866
31		494	471	452	434	418	404	391	380	368	359	350	342	333	326	320	313	857
32		489	466	447	429	414	40	387	376	365	355	346	338	33	323	316	309	848
33		483	461	442	424	409	395	382	371	36	351	342	334	326	319	312	306	839
34		478	456	437	419	404	391	378	·367	356	347	338	331	322	316	309	303	829
35		472	450	·431	414	399	386	373	362	352	343	334	327	318	312	·305	299	819
36		467	445	426	409	395	382	369	358	348	339	330	323	315	308	302	295	809
37		461	439	421	404	389	377	364	·345	343	334	326	319	311	304	298	291	799
38		455	433	·415	399	384	372	359	349	339	330	321	314	306	300	294	288	788
39		448	427	·409	393	379	367	354	344	334	325	317	310	302	296	290	284	777
40		442	421	404	388	374	361	349	339	329	321	312	306	298	292	286	279	766
41		435	415	·397	382	368	356	344	334	324	316	307	301	293	287	281	275	755
42		429	409	391	376	363	351	339	329	319	311	303	296	289	283	277	271	743
43		422	402	·385	370	357	345	333	324	314	306	298	292	284	278	273	267	731
44		415	395	379	364	351	339	328	318	309	301	293	287	280	274	268	262	719
45		408	389	373	358	345	334	322	313	304	296	288	282	275	269	264	258	707

That due to the tenacity of mortar would probably not exceed 20 lbs on the square inch, or 2,880 lbs per square foot, and its moment = 1,440 b^2 (or according to Barlow's article 121, where he treats a wall as if it were a beam = 500 b^2), but this effect will usually exceed the effect of the weight of the mass of the foundations which will be only $\frac{W_1 db^2}{2}$ where d = depth of foundations and b is the breadth, neglecting spread of footings, or what will be simplest, substitute h_1 the height over foundation bed for h in expression $\frac{Wh b^2}{2}$

It seems to me from the above, and considering the means we have of decreasing the pressure of the earth by packing and consolidation, that no increase to the theoretical breadth, obtained for loose earth, by the above tables or equations, will be necessary in practice, provided only that the back of the wall be well drained and that no saturation of the earth by water be permitted It is, however, satisfactory to practical men to have a tangible margin of strength, so that I propose the following practical additions be made to the breadth of walls

$\frac{1}{10}$ b for well drained banks with horizontal surfaces

$\frac{1}{6}$ b ,, ,, sloping surfaces

$\frac{1}{4}$ b for walls when the material is considered treacherous, or for dams over rivers where floods have considerable velocity

In the foregoing Tables, the wall is supposed to be vertical at back, but when it leans backwards or forwards the value of the pressure changes, as will be seen further on, according to the inclination of supporting plane to the vertical So long as the wall reclines, the breadth obtained from the tables will give a wall having an excess of strength, and the error will be on the right side, but when the wall has a back which overhangs or leans forward, it will be necessary to add something to the strength of the wall The amount of this extra strength will not, however, be very great, because the stability of the wall is helped by the moment of the weight of the mass AaB (*Fig* 2), vertically over the overhanging plane, and it will be found that the stability thereby produced is, in most cases, nearly equal to the increase of pressure caused by the increase to the prism of maximum horizontal pressure, due to the inclination of the plane AB, when the surface of the bank is horizontal the rest of the mass AaB is $\frac{Wh^2 \tan\beta}{2}$, and its leverage is

$x - \frac{1}{3} h \tan \beta$, therefore, the force tending to stability $F = \frac{Wh^2 \tan \beta}{2}$ $(x - \frac{h \tan \beta}{3})$, where

β, is the angle of batter of wall at back,

x, the breadth of an approximate wall

The breadth x will be obtained by approximations in the following manner —

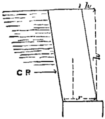
Of necessity in practice the wall will have somewhat a triangular shape, so that $x = qb$, q being a co-efficient of b, as in Table No III, page 327, depending on the form of the wall determined on

First, we obtain x for the wall, on the assumption that the back is vertical, from the value $b = \sqrt{\frac{2}{3} \frac{2}{W_1}}$ or by Table III, in page 331, and thus an approximate value for F Next, we obtain the true value of P for a bank supported by an overhanging plane (*see* equations 5, 7, 9, further on,) and obtain a mean value for x when $b = \sqrt{\frac{2}{3} \frac{(P - F)}{W_1}}$, this value will probably be near enough for practice, but a closer approximation may be made by obtaining a new value for F, and thence a truer value for x

In the case of a bank whose surface slopes up, the value of the moment of the weight of the prism AaB will change somewhat It will be better in this case to make a geometrical approximation to the value of the leverage, as an equation for its determination would afford little practical advantage, in proportion to the difficulty of obtaining the value of x by it The area may be obtained mathematically, and the position of the centre of gravity by construction, whence closer approximate values for x and F An expression for the weight of AaB is in this case $\frac{Wh^2}{2}$ $\tan \beta \, (1 + \tan \beta \tan \iota)$

The two following cases of walls, not mentioned in the first part of this paper, are here inserted

Fig 7



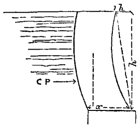
Let $i\,h$ be the total batter in each case, one being a straight batter, the other a curved. Equating the moments for the first case (*Fig* 7),

$$\frac{W_1 h b^2}{2} = W_1\, h\, x\left(\frac{x}{2} + \frac{i\,h}{2}\right), \text{ and } b^2 = x + i\,h x$$

Whence $x = \sqrt{b^2 + \left(\frac{i\,h}{2}\right)^2} - \frac{i\,h}{2}$

and in the second case (*Fig* 8), supposing the curve to be parabolic, we have—

Fig 8



$$\frac{W_1\, h\, b^2}{2} = W_1\, h\, x\left(\frac{x}{2} + \tfrac{2}{3}\, i\, h\right) \therefore b^2 = x^2 + \tfrac{4}{3}\, i\, h\, x$$

Whence $x = \sqrt{b^2 + \left(\tfrac{2}{3}\, i\, h\right)^2} - \tfrac{2}{3}\, i\, h$, which is also very nearly true if the curve of the force be circular, *see* Rankine's Civil Engineering, Art 268

The present paper lays no claim to originality, as it merely aims at presenting in a condensed and practical form, the deductions of others that I find scattered up and down in the various authorities I have now the opportunity of consulting In most authors I find a want of connected formula for the various cases of earth pressure, and often a want of any distinct enunciation of the theory from which the formulæ are obtained, I trust, therefore, I may be excused in presenting the following investigation of earth pressures, based chiefly on incomplete Notes of Lectures, delivered some years ago by Dr Hart, L L D, F T C D, on the subject

In investigating the pressure of earth it is assumed that—

1 The earth is loose or dry

2 Has no cohesion

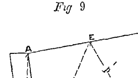
3. The plane retaining it being perfectly smooth, the friction of earth against it is neglected

4 And that there is here equilibrium between the moments of the pressure of the bank, and those of the stability of the wall

Loose earth, may be considered to be a collection of particles free to move on each other, and when it is filled in behind a fixed plane, the resistance of this plane retains the mass, but if the plane be removed the particles of the earth will slip among and over each other till equilibrium is obtained, this will not be till the verticals through their centres of gravity make, with the perpendicular to a certain plane in the mass, an angle equal to the limiting angle of friction This plane is the natural slope, and the angle, which it forms with the horizontal, is the angle of repose, or limiting angle of friction, and its tangent = co-efficient of friction of earth on earth

In *Fig* 9, let this plane be represented by BC, the angle of repose by $\theta°$ ABC is the prism supported by the plane AB representing the back of a retaining wall The earth below the plane BC is held in equilibrium by its internal friction, we may therefore neglect it The mass in the prism ABC being just on the point of slipping, we may consider that the effect of friction along its surface in the direction of B is neutralized by its inclination, or that friction does not exist in the mass, as an infinitely small force will cause motion It will not affect the reasoning therefore to consider this plane BC to be a horizontal plane, on which friction does not exist, and while it is horizontal no pressure will be excited against AB Let the plane BC be raised through any angle ε, the horizontal pressure will become by the principle of the inclined plane—

Fig 9



$$P = W_2 \tan \varepsilon$$

where W_2 = weight of prism ABC

ε = angle of elevation of the plane BE over BC

For the unit of breadth of the prism $W_2 = WA$

where W = the weight of a cubic foot of the material retained

A = the area of the triangle ABE

$$\text{Therefore } P = WA \tan \varepsilon$$

There will be an elevation of this plane BE, at which the pressure becomes a maximum

This will be when the position of the plane BE is such that the area which it forms with a perpendicular let fall on BC, from where it cuts the surface of the bank AC, is equal to the area it forms with the surface and the plane AB, or, $A = BEy$

To prove that such is the case by calculus Let A tan ϵ be sought to be a maximum, then by the principle if maxima and minima

$$d\,A \tan \epsilon + A \sec^2 \epsilon\, d\,\epsilon = 0 \quad \text{And as } d\,A = -\frac{l^2}{2}\, d\,\epsilon \;(l \text{ being } By)$$

$$\therefore -\frac{l^2}{2}\, d\,\epsilon \tan \epsilon + A \sec^2 \epsilon\, d\,\epsilon = 0$$

$$\text{Whence } A \sec^2 \epsilon = \frac{l^2}{2} \tan \epsilon, \text{ but } \sec^2 = \frac{1}{\cos^2}$$

$$A = \frac{l^2}{2} \tan \epsilon \cos^2 \epsilon,$$

$$= \frac{l^2}{2} \sin \epsilon \cos \epsilon, \text{ but } l \sin \epsilon = p' \text{ and } l \cos \epsilon = By$$

$$A = \frac{p' \times By}{2} \qquad (1)$$

which is $A = BEy$ = area of wedge of maximum horizontal pressure The expression for the maximum horizontal pressure of banks of loose earth is therefore

$$P = WA \tan \epsilon \qquad (2)$$

and as shown above $A = \frac{p'\,By}{2}$ and also $\tan \epsilon = \frac{p'}{By}$

$$\therefore \quad P = \frac{W\,p'^2}{2} \qquad (3)$$

another general expression for the horizontal pressure of all cases of banks against all planes of support

It only therefore remains to obtain values for the unknown terms A, tan ϵ and p' in terms of the known data which are usually—

θ°, the angle of repose, or, its tangent the co-efficient of friction

h, the vertical height of the plane AB

ι°, the angle of slope of the surface AC of the bank

β°, the angle of batter (from the vertical) of the plane AB

For practical purposes it will be sufficient to consider six cases of banks of earth, and to obtain values for the general equations (2), (3), for each

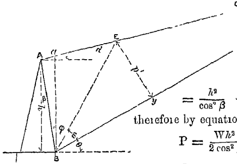
I shall also, although the expressions obtained can be shown to be equal to one another, give separate equations for each case, deduced from both of these general equations

In the following formulæ—

ϕ°, is supposed to be the angle between the plane AB and the plane BE, called the plane of maximum effect

λ°, is the supplement of $\phi + \angle$ BAE

CASE I Where the surface slopes up from the top of the wall at any inclination less than θ°, and the retaining plane AB over-hangs or reclines *Fig* 10



$$A = \frac{\overline{AB}^2 \sin\phi \,\sin(\phi+\lambda)}{2\sin\lambda}$$

$$= \frac{h^2}{\cos^2\beta}\,\frac{\sin\phi\,\sin(\phi+\lambda)}{2\sin\lambda} \qquad (4)$$

therefore by equation (2)

$$P = \frac{Wh^2}{2\cos^2\beta}\,\frac{\sin\phi\,\sin(\phi+\lambda)}{\sin\lambda}\,\tan\epsilon \qquad (5)$$

or $p' = \overline{BE}\sin\epsilon$, and $BE = \dfrac{\overline{AB}\sin(\phi+\lambda)}{\sin\lambda}$

$$\therefore\ p' = AB\,\frac{\sin(\phi+\lambda)}{\sin\lambda}\sin\epsilon$$

$$\therefore\ p'^2 = \frac{h^2}{\cos^2\beta}\,\frac{\sin^2(\phi+\lambda)}{\sin^2\lambda}\sin^2\epsilon \qquad (4a)$$

wherefore by equation (3) $P = \dfrac{Wh^2}{2\cos\beta}\,\dfrac{\sin^2(\phi+\lambda)}{\sin^2\lambda}\sin^2\epsilon \qquad (5a)$

In this case $\phi^\circ = \overline{(90^\circ \pm \beta^\circ) - (\theta+\epsilon)}$,

$\lambda^\circ = \left[(\theta+\epsilon) - i\right]$ and ϵ is got from Neville's expression—

$$\left.\begin{aligned} &\text{Tan}\,\epsilon = \sqrt{\tan^2(\theta-i) + \tan[(90\pm\beta)-\theta]\tan(\theta-i)} - \tan(\theta-i) \\ &\text{or (Doctor Hart's)} \\ &\text{Tan}\,\epsilon = \tan(\theta-i)\left\{\sqrt{\frac{\sin\overline{(90\pm\beta-i)}}{\sin(\theta-i)\ \cos(90\pm\beta-\theta)}-1}\right\}. \end{aligned}\right\} \qquad (5b)$$

This case may be looked upon as a general one, and the equations for all the other cases deduced from it by substituting particular values of ϕ, λ, β In these angles where $\pm\beta^\circ$ is given, the positive sign is used when the plane AB over-hangs, and the negative when it reclines

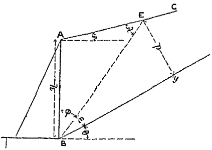
The sign of the angle i, given, is that of the most usual case of the bank surface sloping up when the bank slopes down, the sign of i will reverse

The equations (4), (4*a*), (5*b*), are also general

I shall, however, continue to deduce the equations for each case from equations (2), (3).

CASE II Where the surface slopes up at any angle less than θ, and when the plane AB is vertical—

Fig 11



Here $A = \frac{h^2}{2}\frac{\sin\phi\sin(\phi+\lambda)}{\sin\lambda}$ and by equation (2)

$$P = \frac{Wh^2}{2}\frac{\sin\phi\sin(\phi+\lambda)}{\sin\lambda}\tan\varepsilon \quad (6)$$

also by equation (3)

$$P = \frac{Wh^2}{2}\cdot\frac{\sin^2(\phi+\lambda)}{\sin^2\lambda}\sin^2\varepsilon \quad (6a)$$

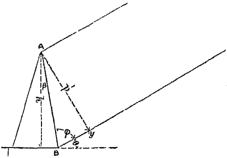
(both these equations follow from equations (5) and (5a) when $\frac{h}{\cos\beta} = h$)

In this case $\phi = 90 - (\theta + \varepsilon)$, $\lambda = \theta + \varepsilon - \iota$,

and $\tan\varepsilon = \sqrt{\tan^2(\theta-\iota) + \tan(90-\theta)\tan(\theta-\iota)} - \tan(\theta-\iota)$ (6b)

CASE III Where the surface slopes up at an inclination equal to the natural slope ($\iota = \theta$) and the retaining plane AB either over-hangs or reclines

Fig 12



By equation (2) $P = A \tan\varepsilon$, but (equation 1) $A = \frac{Byp'}{2}$ and $\tan\varepsilon = \frac{p'}{By}$ ∴ as in equation (3), $P = \frac{wp'^2}{2}$

$p' = AB\sin\phi$

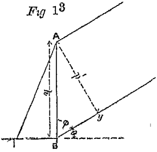
and $AB = \frac{h}{\cos\beta}$

$$\therefore P = \frac{Wh^2\sin^2\phi}{2\cos^2\beta} \quad (7)$$

here $\phi = (90 \pm \beta) - \theta$

CASE IV Where the surface slopes up at an inclination equal to the natural slope ($\iota = \theta$) and the retaining plane AB is vertical

Fig 13



This may be considered as a case of the above, where

$AB = \frac{h}{\cos\beta} = h$ in equation (7)

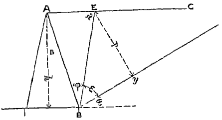
$$\therefore P = \frac{Wh^2}{2}\sin^2\phi$$

$$= \frac{Wh^2}{2}\cos^2\theta \quad \ldots\ldots\ldots \quad (8)$$

CASE V When the surface is horizontal and the retaining plane AB either over-hangs or reclines

This case may be considered an example of Case I, where $\lambda = \theta + \varepsilon$, then by equations (2), (4),

Fig 14



$$P = \frac{Wh^2}{2\cos^2\beta} \frac{\sin\phi \sin[\phi + (\theta + \varepsilon)]}{\sin(\theta + \varepsilon)} \tan\varepsilon$$

$$= \frac{Wh^2}{2\cos^2\beta} \frac{\sin\phi \tan\varepsilon}{\sin(\theta + \varepsilon)} \quad (9)$$

or by equations (3), (4*a*),

$$P = \frac{W\,h^2}{2} \frac{\sin^2\varepsilon}{\sin^2(\theta + \varepsilon)} \quad (9a)$$

where $\phi = (90 \pm \beta) - (\theta + \varepsilon)$, $\lambda = \theta + \varepsilon$, and the value of

$$\tan\varepsilon = \sqrt{\tan^2\theta + \tan(90 \pm \beta - \theta)\tan\theta} - \tan\theta \quad (9b)$$

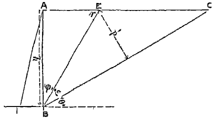
another value for the pressure is—

$$P = \frac{Wh^2}{2}[\cot(\theta + \varepsilon) \pm \tan\beta]\tan\varepsilon \ . \quad (10)$$

CASE VI Where the surface of bank is horizontal and the plane AB vertical

This may be considered a special example of Case V, where $\iota = 0$

Fig 15



$\frac{h}{\cos\beta} = h$, $\lambda = \theta + \varepsilon$, $\phi = \varepsilon$, or in equation (2) $A = h^2 \tan\phi$

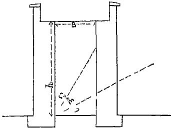
$$\left.\begin{aligned} &\therefore P = \frac{Wh^2}{2}\tan^2\varepsilon \\ &\text{and in equation (3) } p' = h\tan\varepsilon \\ &\therefore P = \frac{Wh^2}{2}\tan^2\varepsilon \end{aligned}\right\} \quad (11)$$

in this case $\varepsilon = \phi$, because the triangle BAE and BE*y* are equal and similar, and therefore, $\varepsilon = \left(\frac{90^\circ - \theta}{2}\right)$ . . . (11*b*)

It sometimes happens that the wedge of maximum horizontal pressure, AEB, is cut off by a vertical plane between A and E, as in the case of bank retained between two walls—such as the retaining walls

of bridge approaches—where the breadth of top of bank B between the walls is less than $h \tan \varepsilon$,

Fig 16



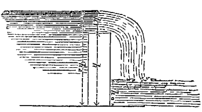
Here A becomes $h\,\mathrm{B} - \left(\frac{\mathrm{B}^2 \cot \varepsilon}{2}\right)$

$$\mathrm{P} = \mathrm{W}\,\mathrm{B}\left(h \tan \varepsilon - \frac{\mathrm{B}}{2}\right) \qquad (12)$$

The moment of these pressures $\mathrm{P}\,\frac{h}{3}$ may be equated with the moments of stability of the walls against which they act, as already shown

When a wall is built across a stream, as in the case of a weir or bundara, the pressure against it will be composed of the hydraulic pressure P, and the shock of the current P_1

Fig 17



First, if we neglect the back water h_0 Let h be height of dam, h_1 height of flood over it $\mathrm{P} = 62{\cdot}5\,h\left(\frac{h}{2} + h_1\right)$, and since the depth of the centre of pressure from the surface $= \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}$ where h_2 is the total height from base of wall to surface $= h + h_1$, and the moment $\mathrm{M}_{\mathrm{P}} = 62\tfrac{1}{2}h\left(\frac{h}{2} + h_1\right)\left(h_2 - \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) \qquad . \quad . \quad (13)$

The shock also $\mathrm{P}_1 = \frac{62{\cdot}5}{64}\,a\,\mathrm{V}^2$, and its moment $\mathrm{M}_{\mathrm{P}_1} = \frac{976\ h^2\ \mathrm{V}^2}{2}$ (14)

Where a is the area of wall or weir, which for unit of length becomes equal to h,

V, the velocity of the stream in feet per second

The sum of these moments tending to over-turn the wall

$$\mathrm{M}\,(\mathrm{P} + \mathrm{P}_1) = 62\tfrac{1}{2}\,h\left(\frac{h}{2} + h_1\right)\left(h_2 - \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{976\,h^2\,\mathrm{V}^2}{2} \qquad . \,(15)$$

When back water exists it must be taken into account as tending to the stability of the wall, and therefore to the reduction of the effect of $\mathrm{M}\ (\mathrm{P} + \mathrm{P}_1)$.

Let the height of the back water, outside the dam be h_0, then the moment of its pressure

$$\mathrm{M}_{\mathrm{P}_2} = \frac{31{\cdot}25\,h_0^3}{3}$$

and $M_{(P + P_1 - P_2)} =$

$$62\tfrac{1}{2}\, h\left(\frac{h}{2} + h_1\right)\left(h_2 - \left[\frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1}\right]\right) + 488\, h^2\, V^2 - 10\,4\, h_0^3 . \quad (16)$$

whence by equation (15)

$$b = \sqrt{\frac{125}{W_1}\left(\frac{h}{2} + h_1\right)\left(h_2 - \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{976\, h\, V^2}{W_1}}$$

or equation (16)

$$b = \sqrt{\frac{125}{W_1}\left(\frac{h}{2} + h_1\right)\left(h_2 - \frac{2}{3}\,\frac{h_2^3 - h_1^3}{h_2^2 - h_1^2}\right) + \frac{976\, h\, V^2}{W_1} - \frac{20\,8\, h_0^3}{W_1\, h}}$$

J H DHARWAR

No XLVII

RANGOON CUSTOM-HOUSE AND BONDED WARE-HOUSE.

Estimate of the Cost of Erecting a Custom-House and Bonded Warehouse at Rangoon, British Burmah BY CAPTAIN J M WILLIAMS, *Exec Engineer*

Custom house

c ft		RS
116,495 5	Brick-work in mortar, at Rs 30 per 100,	34,949
s ft		
92,275 96	Mortar plaster, at Rs 6 per 100,	5,537
92,275 96	White-washing, at Rs 0-8 per 100, . .	461
c ft		
17,197 5	Brick rubbish and sand, at Rs 4 per 100,	688
5,189 25	Brick on edge at Rs 25 per 100, .	1,282
s ft		
6,980	Penang tile flooring, at Rs 12 per 100,	838
c ft		
2,703 04	Teak timber in floor, at Rs 170 per 100,	4,595
s ft		
7,365	Two layers Penang tiles, at Rs 22 per 100,	1,620
7,365	Three-inch terracing, at Rs 5 per 100,	368
c ft		
2,027 19	Teak timber in roof, at Rs 170 per 100,	3,446
s ft		
9,072	Three layers Penang tile, at Rs 32 per 100, .	2,903
9,072	Six-inch terracing, at Rs 8 per 100,	725
4,152	Doors and windows, at Rs 1-4 per foot, . .	5,180
c. ft		
810	Teak timber in chowket, at Rs 180 per 100,	1,458
No		
2	Main stair cases, at Rs 800 each, . . .	1,600
2	Small do at Rs 500 each, .	1,000
16	Columns, at Rs 100 each, . .	1,600

		Rs
s ft		
42,079 61	Painting, three coats, at Rs 5 8 per 100,	2,314
	Total Rupees,	70,564
	Add contingencies, at Rs 5 per cent,	3,528
	Total for Custom-house,	74,092

Bonded Warehouse

c ft		
117,876	Brick work in mortar, at Rs 30 per 100,	35,212
s ft		
87,196 13	Mortar plaster, at Rs 6 per 100,	5,231
87,196 13	White-washing, at Rs 0-8 per 100,	436
c ft		
25,009 5	Brick rubbish and sand, at Rs 4 per 100,	1,000
62,523 74	Brick-on edge, at Rs 25 per 100,	1,563
s ft		
8,650	Penang tile flooring, at Rs 12 per 100,	1,036
c ft		
4,474 2	Teak timber in floor, at Rs 170 per 100,	7,606
s ft		
8,978 5	Two layers of Penang tiles, at Rs 22 per 100,	1,974
8,973 5	Three-inch terracing, at Rs 5 per 100,	448
c ft		
4,472 2	Teak timber in roof, at Rs 170 per 100,	7,606
s ft		
9,948	Three layers of Penang tiles, at Rs 32 per 100,	3,183
9,948	Six-inch terracing, at Rs 8 per 100,	797
4,196	Doors and windows, at Rs 1-4 per foot,	5,245
c ft.		
730 5	Teak timber chowket, at Rs 180 per 100,	1,314
No		
1	Stair-case,	1,000
28	Nine-inch columns, iron, at Rs 100 each,	2,800
28	Six inch do at Rs 75 each,	2,100
s. ft		
51,435 6	Painting, three coats, at Rs 5 8 per 100,	2,829
	Total Rupees,	81,380
	Add contingencies at Rs 5 per cent,	4,069
	Total for Bonded Warehouse,	85,449

Examining Shed

c ft		
85,605	Brick-work in mortar, at Rs 30 per 100,	2,568
17,226	Brick rubbish in sand, at Rs 4 per 100,	689
2,871	Brick on-edge, at Rs 25 per 100,	717
s ft		
6,586	Penang tile flooring, at Rs 12 per 100,	790
1,290	Mortar plaster, at Rs 6 per 100,	77
1,290	White-washing, at Rs 0-8 per 100,	6
15,840	Iron tiles roofing complete, including frames, at Rs 50 per 100,	7,920

Examining Shed (Continued)

cwt		Rs
720	Lead gutter, 6 lbs to the foot = 38.57 cwt, at Rs 25,	964
No		
10	Iron columns, at Rs 75 per 100,	750
c ft		
21,114	Earthwork, at Rs 1-8 per 100,	316
	Total Rupees,	14,797
	Add contingencies, at Rs 5 per cent,	740
	Total for Examining Shed,	15,537

Surrounding Wall

c ft		
50,661	Brick-work in mortar, at Rs 30 per 100,	15,199
s ft		
43,108	Mortar plaster, at Rs 6 per 100,	2,586
43,108	Color washing, at Rs 0 8 per 100,	215
ft		
296.5	Panel doors, at Rs 1 4 per foot,	370
593	Painting, three coats, at Rs 5-8 per 100,	32
No		
2	Iron gates, at Rs 500 each,	1,000
	Total Rupees,	19,402
	Add contingencies, at Rs 5 per cent,	970
	Total for Surrounding Wall,	20,372

Out Offices

c ft		
12,021.5	Brick-work in mortar, at Rs 30 per 100,	3,606
s ft		
8,476.5	Mortar plaster, at Rs 6 per 100,	508
8,476.5	White washing, at Rs 0 8 per 100,	43
4,032	Penang pan-tile roof complete, at Rs 38 per 100,	1,532
608	Panel doors, at Rs 1-4 per foot,	760
c ft		
10,203	Brick rubbish and sand, at Rs 4 per 100,	408
2,550.74	Brick on edge, at Rs 25 per 100,	637
s ft		
3,401	Penang tile flooring, at Rs 12 per 100,	408
1,216	Painting, three coats, at Rs 5 8 per 100,	67
	Total Rupees,	7,969
	Add contingencies, at Rs 5 per cent,	398
	Total for Out Offices,	8,367
	Total for Custom-House,	74,092
	Total for Bonded Warehouse,	85,449
	Total for Examining Shed,	15,537
	Total for Surrounding Wall,	20,372
	GRAND TOTAL, RUPEES,	2,03,817

CALCULATIONS FOR IRON COLUMNS FOR CUSTOM-HOUSE

Columns for Upper Story to Support Roof

Weight of Roof

Bearing beams	$1 \times 11' \times \frac{15 \times 10}{144} \times 46\ 61 = 584\ 07$	
Cross do,	$2 \times 10' \times \frac{10 \times 6}{144} \times 46\ 61 = 388\ 41$	
Joists,	$18 \times 5\frac{1}{2} \times \frac{4 \times 4}{144} \times 46\ 61 = 512\ 71$	1,485 19
Terracing and flat tiles	$11 \times 10 \times 65 =$	7,150 00
	Total dead weight on each column,	8,585 19 lbs.

Let W = breaking weight for long columns by Hodgkinson's formula $= 44\ 34 \frac{D^{3\ 6} - d^{3\ 6}}{L^{1\ 7}}$, D being external diameter = 4 inches, d internal diameter = 3 inches, L the length = 15 feet In this case $44\ 34 \frac{4^{3\ 6} - 3^{3\ 6}}{15^{1\ 7}} = 42\ 11$, also c = crushing force of iron (44 tons) $\times$ sectional area of columns $= 0\ 7854 \times (4^2 - 3^2) \times 44 = 241\ 9$, then the actual breaking weight for short columns $= \frac{W\,c}{W + \frac{3}{4}c} = 45\ 57$ tons, which taking the factor of safety as 4, gives the working load $= \frac{45\ 57}{4} = 11\ 34$ tons, or 25,401 lbs, thus giving an excess of strength sufficient for all contingencies

---

Columns on Lower Story to Support Flooring, with Weight of Columns and Roof above

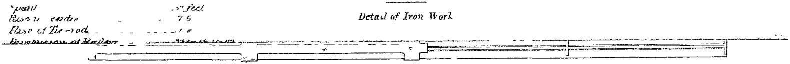
Floor

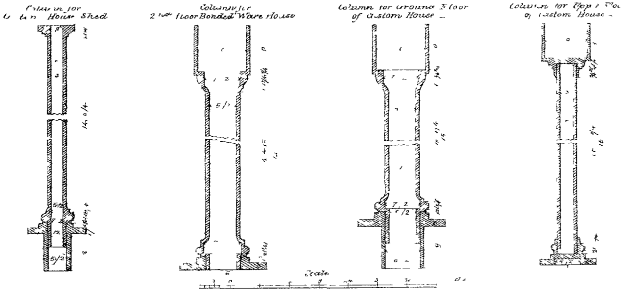
Bearing beam	$11 \times \frac{17 \times 10}{144} \times 46\ 61 = 605\ 28$	
Cross do,	$2 \times 10 \times \frac{13 \times 9}{144} \times 46\ 61 = 757\ 41$	
Joists,	$18 \times 5\frac{1}{2} \times \frac{6 \times 4}{144} \times 46\ 61 = 769\ 06$	2,131 75
Weight of tiles and mortar,		7,150 00
" of goods $11 \times 10 \times 400$,		44,000 00
" of columns of upper story,		600 00
" of roof and each column,		8,585 19
	Total dead weight on each column,	62,466 94 lbs

Let W = breaking weight of long columns $= 44\ 34 \frac{D^{3\ 6} - d^{3\ 6}}{L^{1\ 7}} = 284\ 05$ tons, where D = external diameter = 7 inches, and d internal diameter of

RANGOON CUSTOM-HOUSE

Detail of Iron Work





ITHO T.C. PRESS.

column $= 5\frac{1}{2}$ inches, L = length in feet = 15, also c = crushing force of iron $\times$ sectional area of column $= 44 \times 0\ 7854 \times [7^2 - (5\frac{1}{2})^2] =$ 647 95, then crushing weight for short column $= \frac{W\,c}{W + \frac{3}{4}c} =$ 239 tons

Taking the factor of safety as 4, this will give a safe working load of $\frac{239}{4} =$ 59 75 tons, or 133,840 lbs, which will be sufficiently strong for all contingencies

---

CALCULATIONS FOR IRON COLUMNS FOR BONDED WAREHOUSE

Columns for upper story support a roof of the same weight (8,585 lbs) as that on Custom-house, and are of the same size, viz, 4 inches external and 3 inches internal diameter, 15 feet long, the breaking weight being 45 57 tons, with safe working load of $\frac{45\ 57}{4} =$ 11 34 tons, or 25,401 lbs

---

Columns for second story support a total dead weight the same as the columns of lower story of Custom-house, viz, 62,466 94 lbs, and being of the same dimension, viz, 7 inches outside and $5\frac{1}{2}$ inches internal diameter, 15 feet long, sustain the same safe working load of 59 75 tons, or 133,840 lbs

---

Columns for lower story support weight of first floor, weight of second story columns, and weight upon second story columns

Weight of first floor, same as weight of second floor,	=	53,281 75
Weight of second story columns,	=	950 00
Weight on ,,	=	62,466 94
Total,		1,16,698 69

Let W, breaking weight of long column $= 44\ 34 \frac{D^{3\cdot6} - d^{3\cdot6}}{L^{1\cdot7}} =$ 720 27 tons, where D external diameter = 9 inches, and d = internal diameter = 7 inches, and L = length of column in feet = 15 feet, also c = crushing force of iron $\times$ sectional area of columns $= 44 \times 0\ 7854 \times (9^2 - 7^2) =$ 1,105 84, then actual crushing weight of short column $= \frac{W\,c}{W + \frac{3}{4}c} =$ 514 tons.

Taking the factor of safety as 4, this gives a safe working load for the column of $\frac{514}{4} = 128.5$ tons, or 2,87,840 lbs, which leave an excess of strength sufficient for all contingencies

---

CALCULATIONS FOR GIRDERS AND COLUMNS FOR SHED OF CUSTOM-HOUSE

The columns are to be 15 feet long, placed at intervals of 20 feet apart, each supporting four trusses with roof covering and one Girder of weight estimated below

WEIGHT ON GIRDERS

	feet	lbs per foot	lbs
Rafters,	10	8 25	330
Struts,	20	5 00	100
Purlins,	80	2 50	200
Tie-rod,	37	3 32	123
King-bolt,	6 5	2 00	13
Queen „	6 5	1 00	6 5
Ridge,	5	4 00	20
„ plate,	5	12 00	60
Tiles,	5 × 40	1 50	300
Gutter,	5	27 64	138 2

Total weight of truss and covering, = 1,290 7
Total weight on each girder 1,290 7 × 3 = 3,872 1

leaving the pressure of the wind out of consideration, as the roof is protected by the buildings

Let W = breaking weight of Girder

L = distance between points of support, = 20 feet
D = whole depth, = 10 inches
d = „ lower flange, . = 8 „
B = breadth of „ . = 8 „
b = thickness of web and rib, = 1 „

$$\text{then } W = \frac{2}{3}\,\frac{BD^3 - (B-b)\,d^3}{DL} = 14.72 \text{ tons}$$

This gives a safe working load of $\frac{14.72}{4} = 3.68$ tons, or 8,243 lbs, to meet a dead weight of 3,872 lbs equally distributed at three points, thus giving an excess of strength sufficient to meet any occasional pressure from wind, &c.

WEIGHT ON COLUMNS

Each column supports four trusses with roof covering, and weight of girder

Weight of 4 trusses = 4 × 1,290 7	= 5,162 8
Weight of girder (estimated at),	1,768
	6,930 8 lbs

Columns are 15 feet long, 4 inches external and 3 inches internal diameter, which gives, by previous calculation, a safe working load of 11 34 tons, or 25,401 lbs , this being sufficiently strong to meet any occasional strain from wind, &c

J M WILLIAMS

No XLVIII.

SURVEYOR GENERAL'S REPORT, 1858-1861.

Abridged from the General Report on the Surveys of the Bengal Presidency, for the Seasons 1858-59, 1859-60 *and* 1860-61. By Lieut.-Col. H. L. Thuillier, R. A., *Surveyor General of India.*

General Remarks.—It is proposed, in the present Report, to treat of the whole of the Revenue Surveys now in course of execution, under the several Governments* of the Bengal Presidency, for the three seasons extending from the 1st October, 1858, the commencement of the professional season of 1858-59, to the 30th September 1861, the end of season 1860-61. I propose, also, to recapitulate and generalise the leading results attained, as detailed specifically under the head of each Survey, so as to afford a better idea of the real nature and extent of the working of the Department.

Number of Survey parties employed.—The Department has been very actively engaged, and very extensive progress has been effected. The number of regular parties has been increased from 12 to 14; during the ensuing season there will be 15, besides three other small detached Establishments, making 18 in all.

Extent of work performed.—The aggregate labors of the 13 parties, employed during the period under review, are as follows, arranged according to their respective Governments:—

* Punjab, North Western Provinces, Bengal, Lower Provinces, Oudh, Central Provinces, Sind.

Number of parties	Jurisdiction	Area surveyed in square miles.	Total Cost			Average rate per square mile			Remarks
			R	A	P	R	A	P	
1	N W Provinces,	4,290	85,615	0	0	19	14	0	Chiefly Revenue
1	Punjab,	14,552	1,68,515	0	0	11	9	0	All Topographical
1	Sind (Bombay),	12,975	1,60,075	0	0	12	5	0	Chiefly Topographical
6	L Prov (Bengal)	23,041	6,44,646	0	0	27	15	7	Chiefly Revenue
2	Central Province,	7,862	2,48,436	0	0	31	9	7	All Revenue
2	Oudh,	2,440	1,16,732	0	0	47	13	5	All Revenue
13	Total for 3 Seasons,	65,160	14,24,019	0	0	21	14	0	

The above shows the very large area of sixty-five thousand one hundred and sixty square miles of country which has come under either the Revenue or mixed Revenue and Topographical operations by the Revenue Survey Establishments, and been completed during the three seasons The area may be better understood, when I state that it equals about one-half of the entire British Islands, or of the Prussian Kingdom, and about a quarter of that of the whole of France The proportion of the former description of Survey is 38,034 square miles to 27,27,126 square miles of the latter, and the mean annual average progress is 21,720 square miles The mean average area performed by each of the 13 Establishments annually is 1,670 square miles

Scales and description of Survey —The area laid down on the Revenue detail system is on the scale of four inches to the mile, the limits of every village being separately defined and mapped on that scale, as well as generalised and reduced to one inch The portion taken up topographically only, is surveyed on the one inch scale, and shows the general features of the country and all details, including territorial sub-division, up to the capability of the scale, but without the village boundaries, which are not defined or recorded, not being required at present

Cost and Rates —The total cost of the entire operations comes to Rs. 14,24,019, on which the general average rate per square mile is

Rs 21-14 The cost of the Revenue Detail Survey is Rs 9,36,133, giving an average rate of Rs 34-8 per square mile, and the expenses of the Topographical Operations are Rs 4,87,886, yielding an average rate of Rs 12-13 per square mile, the difference being nearly in the proportion of 3 to 1 in the cost of the former over the latter

It will be observed that great diversity of rates prevails under the several jurisdictions This is caused by various local circumstances, the peculiarity and difficulty of the country, and by the difference in the style of the operations over certain areas The mixture of Topographical with Revenue work tends to bring down the general average

The above results are submitted as in every way highly satisfactory and encouraging For the very moderate cost of Rs 21-14 per square mile, we have an excellent first Survey of an enormous area, well adapted and amply sufficient to meet all present requirements, the whole represented by maps of the most practical description and executed in approved style, on the one inch scale, besides the larger proportion of the area given on the larger scale, of four inches to the mile, in separate village sheets

Districts completed and in progress —The operations have been chiefly directed towards the final completion of the Punjab, the districts of Jhansee and Lullutpoor of the North-Western Provinces, with some of the Native States of Bundelcund, the Nagpoor and Jubbulpoor districts of the Central Province, the districts of Purtaubghur and Oonao of the Oudh Province, the districts of Larkhana, Jacobabad, and Mehur, and State of Khyrpoor of Sind, with the districts of Dinagepoor, Dacca, Furreedpoor, Kooch-Behar and Akyab of the Lower Provinces The whole of the above have been finished, whilst considerable progress has been made in the several other districts still in hand

The blanks are still unfortunately too numerous and extensive to be approximately estimated here as remaining for survey There is still a very wide field whereon to employ the whole of the machinery at present engaged and allowed for the purpose, for very many years to come The chief fields for employment lie in Oudh, in the enormous Central Provinces, in the Non-Regulation Lower Provinces, on the South-West Frontier, on the Eastern Frontier, including the whole of Assam (declared by the Government of Bengal to require a re-survey), and in Sind

Aggregate results for 15 years —The above results, added to the area Surveyed, since 1846-47, the date of the revival of the Revenue Surveys,

after the first Punjab War, give the following aggregate amount of work performed in the 15 seasons elapsed —

Area surveyed in square miles	Total cost	Average rate per square mile
2,37,028	RS 53,52,802	R 22 | A 9

Topographical Surveys —In addition to the Surveys executed by the Revenue Survey Establishments (which are connected with the Civil Department), the regular Topographical Surveys, form a very important part of the Survey of India

The Topographical branch of the Survey Department, originally formed partially from the Staff of the Trigonometrical Branch, has been employed chiefly on the Native States, and in those extensive hilly and wild thickly-wooded parts of the British possessions which could not be treated in any other manner, and are but of small value, of which it is not necessary to have more than a good general or military map of the country, on a moderate scale, for political and administrative purposes These Topographical Surveys are conducted entirely on a Trigonometrical basis, with minor Triangulation of the first class order, executed with a 14-inch Theodolite, the Topographical details being filled in on the one-inch scale by the plane table, and the whole generalised and reduced to quarter-inch scale, by the Executive Surveyors

Number of parties and where employed —Four large parties* have been thus employed for some years past, under their respective Superintending Officers, and a very considerable area has been laid down by their united efforts A fifth Party, drafted chiefly from No 1, has likewise been organised for the ensuing season, to be employed in the Rewah Rajah's Territory, through which the Allahabad and Jubbulpoor Railway passes, where it is of high importance for the Geological Survey to pursue its investigations for the discovery of coal, and this cannot be done without good Topographical Maps, which do not exist at present

* No 1, Gwalior and Central India, Captain D G Robinson, Engineers
No 2, Nizam's Dominions, Circar, J Mulheran, Esq
No 3, Ganjam, Orissa, and Central Provinces Sumbulpoor, and Gurjat States, Major Saxton
No 4, Chota Nagpoor, Kolehan, and Chaibassa, S W Frontier Agency, Captain Depree,
1862 63, No 5, Rewah, Lieutenant W J Murray

Extent of the Topographical Operations.—During the past two seasons, 1860-61 and 1861-62, an area of 16,108 square miles has been Topographically laid down, all on the one inch scale. In accordance with the practice observed, the minor triangulation is always in advance of the detail survey. The above area gives a mean average of 2,051 square miles as the annual out-turn of each party, but this scarcely represents the actual results, as the labor of the triangulation in advance forms an important part of the operations, and cannot well be reduced to a fixed area, whereon to proportion the expense. The nature of the country on which these parties are employed, is, for the most part, exceedingly unhealthy, and hostile to rapid progress.

Cost of the Topographical Operations.—Taking one year with another, and balancing the expenditure each season, on the actual amount of Topography furnished, whereby alone the Map of India can be filled up, the average cost of this description of work (above referred to) heretofore comes to Rs. 13 per square mile.

Remaining for the Topographical Surveys.—The Topographical Survey parties have been employed for several years and achieved much, but there is still a vast deal more to be accomplished, and which we cannot expect to do for a very long period. The ground already covered by these operations extends over the Nizam's Territories (including the assigned Districts), which may be said now to be approaching completion, the Hazara, Jhelum and Rawul Pindi Districts of the Punjaub, the Goomsur, Ganjam, and Orissa Districts, and Guzrat States, brought up from the Southern Presidency, and a portion of the Chota Nagpoor Division, whilst the area remaining to occupy this branch of the Department consists of the whole of the Native States of Rajpootana, Gwalior, Central India, Bundelcund, and Rewah, on this side of India, besides the Native States of Bombay still remaining for Survey, an approximate estimate of the area of the whole of which amounts to the large figure of 319,388 square miles.

THE TRIGONOMETRICAL SURVEY.—The great foundation and basis of both the Topographical and the Revenue Operations is, of course, the Trigonometrical Survey, without the aid of which neither of the former can be made full use of, or proceed systematically. The progress of these interesting and valuable operations made great strides under the successful administration of my predecessor, Sir Andrew Waugh, during the long period he was at the head of the Department, for nearly the whole of which I had the

privilege of acting as his Deputy, whilst superintending the Revenue Surveys This long experience enables me to appreciate to the utmost, and to record my sense of the valuable and hearty support always rendered by that Officer's mode of conducting the Great Triangulation, to meet the necessities and requirements of the Revenue Survey, and to his forethought and great consideration for the important objects of the extension of the Geographical knowledge of India

Present state of the Operations —The division of the duties, on the retirement of Sir Andrew Waugh, placed the superintendence of the Trigonometrical Survey under Major Walker, Bombay Engineers That Officer, in a similar cordial spirit, as described above, has favored me with his views regarding the future extension of the Great Triangulation, and consulted my wishes as to the destination of such of his parties as may become available for fresh work The chart of these operations exhibits the several Meridional and Longitudinal series of the Principal Triangulation already executed, covering a very considerable portion of this vast Empire, and fixing absolutely the true positions of most of the chief cities, towns, and places of importance The Meridional operations, North of the Great Longitudinal Series between Calcutta and Kurrachee, are nearly completed, forming a grid-iron between two great quadrilaterals divided by the Great Arc Series, extending from Cape Comorin to the Himalayas in longitude 78°, and checked by the six Base Lines already measured *

Remaining to be done —In this upper or northern section of the work there are two large blanks remaining to be filled up, one in Eastern Bengal and Assam, comprising the whole of the Lower Provinces east of the meridian of Calcutta, and the other in Rajpootana and Sind, between the Gurhaghur Series on 73° and the Indus Series The former of these blanks requires a Series on the meridian of Dacca in 90° East Longitude, another Longitudinal one, on the Parallel of 23° North Latitude, being a continuation of the Calcutta or Great Longitudinal Series, until it meets the Eastern Frontier, passing through the Cossyah Hills, Sylhet, and Tipperah Meridional Series in 94° East Longitude now in progress, and finally the extension of the North-Eastern or Assam Longitudinal Series, from Gowhatty on the Brahmapootra River, to which point the work is already done, up the Valley of Assam, in a north-east-

* Calcutta, Sonakhoda (Darjeeling Plains) Sironj (Central India) Dehra Dhoon Attock (Chuch Valley), Kurrachee

erly direction, to the limits of the British Frontier on the borders of Thibet and Burmah The whole of the above may be said to be of leading importance, as appertaining to the older British possessions in close proximity to the Metropolis of India, and now well covered by the Revenue Survey.

The second blank requires two small or single Series on the meridians of $69\frac{1}{2}°$ and $71\frac{1}{2}°$, between the Great Longitudinal and the oblique Sutlej River Series, across the desert of Rajpootana and Sind, inhospitable barren tracts, entailing heavy expense in the conduct of Trigonometrical operations, with little or nothing to fix or lay down, and of very secondary importance in a Geographical point of view The above Triangulation will amply provide for the Topographical wants of all Northern India, down to the parallel of 23° Latitude, and with the efforts now making by the several parties employed, may be expected to be completed in a very few years

But there are still large tracts of country in Central and Southern India, in British Burmah, and on the East or Coromandel Coast of the Bay of Bengal, below the Parallel of 23°, which have to be provided for. The chief and largest blank is that contained between the Great Arc and the Coast Series, the triangulation of which has reached Rajamundry, and it is proposed to measure a base of verification at Vizagapatam,* the distance being nearly midway between Calcutta and Madras, during the ensuing season This large ellipsoidal figure, comprising the whole of the late Rajah of Berar's Territory, Gondwana, the Jungle Mehals, Surgoojah, Sumbulpoor, the Khond Country, Goomsur, &c, perhaps the most unhealthy and worst part of India will involve the following triangulation, if the operations are to be carried out in the manner proposed by the former Surveyor General, Sir George Everest, and sanctioned by the late Hon'ble Court of Directors

Projected Principal Triangulation —Three Meridional Series will be required, first, and of the most importance, is the meridian of 80° passing through Jubbulpoor, Seonee, and Nagpoor, where the Revenue Surveys have already made great progress, and only await the triangulation now referred to, for the purpose of being incorporated in the Atlas The next pressing object is, the series on the meridian of 84° passing through Palamow, Sirgoojah, Oodeypoor, Sumbulpoor, Sonepoor, and Goomsur, to

* Since measured, see *anti*, p 180 —[Ed

meet the Coast Series a little below Ganjam, the greater part of this tract of country has been Topographically laid down, or is in course of Survey An intermediate Series on the meridian of 82° passing through Ruttunpoor, Jeypoor, &c, may be taken up These Series will be tied by a cross Longitudinal Series from the new Vizagapatam Base to the Beder Base in the Nizam's Territories, which will form a continuation of the Bombay Longitudinal Series

The above will afford ample employment for many years to come As far as can be at present foreseen, the Trigonometrical parties, as their services become available, will be put on to the work in the order I have given above, after which the remaining wants to complete the whole of India may be taken into consideration They may be said briefly to comprise a short Series for Rangoon or British Burmah on $96\frac{1}{2}°$, and the prolongation of the Eastern Frontier Series down the Coast of Arracan and the Tenasserim Provinces, also the continuation of the Coromandel Coast Series, from Madras to Cape Comorin and Ceylon Base Lines will likewise have to be measured at Vizagapatam, Bangalore, Cape Comorin, Pegu, and Tenasserim

Nearly the whole of the Southern Peninsula has been covered with a net-work of Triangles of different values, some of which are of an inferior order, performed nearly half a century ago, with inferior instruments, and by a less rigorous *modus operandi* than the system introduced by Colonel Everest in 1830, and eventually it may be necessary to revise some of that work, by pursuing a fresh Series on the meridian of Mangalore in 75° Longitude, through Sattara and Belgaum, with extension down the Malabar Coast, to connect at Cape Comorin, a Longitudinal section across the Peninsula in Latitude 13° is also proposed, and the measurement of another base, on the western side, may be ultimately found necessary The southern section of the great Arc from Beder to Cape Comorin, and a section of the Calcutta Longitudinal Series from Seronj to Calcutta, affording, as they do, bases to so many other operations, their revision was always contemplated by the late Surveyor General, as a measure to be postponed only until the completion of such series as are indispensably requisite for the Topographical Surveys

Special Topographical Operations of the Himalayas by the Trigonometrical Branch.—In connection with the Trigonometrical Operations, the

special Topographical Survey of the Himalayas, including the whole of the protected States around Simlah, Sirmoor, Chumba, Kulu, Spiti, Lahoul, Bissahir, together with Kashmeer, Ladakh, Balti, &c , has been for some years in progress, and is still being carried on in the latter country, on the smaller scale of half a mile to the inch, by Captain Montgomerie, Engineers, the valuable and interesting Reports of whose proceedings have of late years been so much before the Government and the public, as described in the Journal of the Asiatic Society, and in my predecessor's Reports to Government These operations, over ground of the most stupendous character, varying in altitude from 22,000 down to 5 or 6,000 feet, and within reach of snowy peaks up to 28,000, have taxed the utmost energies, skill, and resources of the picked Officers and Assistants of the Trigonometrical Department, and have obtained for them the admiration of the scientific European world

Maps and Office Work —From such an area as that above recorded as the result of the Revenue Surveys, it might be expected that the number of Maps and Plans produced would be very large 199 Pergunnah or Main Circuit Maps, on the scale of one mile to the inch, have been rendered These are all large and elaborate Maps, generally of Atlas size (some double), each containing very intricate details, involving much time and labor in their preparation The whole of these have been supplied in duplicate, one copy being for the local Civil authority, thus making a total of 398 to represent the full labors of the Executives for the three seasons The Village Plans, on the scale of 20 chains to the inch, amount to 31,161, in number, or with duplicates, 62,322 These latter Plans are now rendered on imperial sheets, in clusters of villages congregated together, and form a much better and more practical record, than by the old system of giving every village on a separate Register Form, especially when the size of the village is small The village Plan Sheets are most valuable for all purposes of Local Engineering, in laying out Roads, Canals, Railways, and the like, giving a clearer idea of the nature of the ground, by showing a larger area at one view, and being accessible in the Local Collectorates, have afforded much satisfaction

The area and statistical information for each village is recorded separately, on forms which are bound up with the numerical or traverse data, on which the Survey is based, and form complete Field Books , of these 58 volumes have been deposited. The observations and measurements,

ith computations deduced therefrom, of the Main Circuits or chief por-
on of the Professional work, are also recorded in 35 volumes, being
ound up together on the completion of the District. In addition to the
ove, 39 Index Maps, scale four miles to the inch, have been received as
uides to the Season's operations.

District Maps compiled.—Such an enormous amount of work coming in
ery season affords very considerable employment for the Head Quarter
uperintending Office, in the compilation and reduction of the materials,
eir examination and adjustment prior to publication, as well as for the
urpose of reporting on the same. It is the practice of this Office to
deavour to complete each District Map, on the reduced scale, as soon
ter the last Pergunnah or Main Circuit has been surveyed as possible.
ach compilation is therefore carried forward, as far as the materials in
nd will permit, and a preliminary Map of the District is thus prepared
t the Press without any delay, and issued to the local authorities and
blic in this country, whilst the final Map is under preparation for des-
tch to England, to be incorporated in the Atlas. Two important
jects are thus gained, viz., the early practical use and distribution of
e survey materials in this country, where they are so urgently needed,
d likewise, by the circulation of a first edition of the Map in the hands
those who know the District well, the correction of inaccurate ortho-
aphy or such other items as may be susceptible of improvement, the
sertion of new roads, or the addition of railways or other alterations,
ected since the date of Survey, is secured.

Lithographic Branch.—In connection with the Drawing Office is the
thographic Press, for the multiplication of the Maps, by transfer draw-
g on stone. This branch of the Department has only been in existence
ew years, but it has made rapid strides with very inadequate means,
d the present style of our printed impressions is equal to that produced
England. The Establishment is but small, and was fixed when the
-turn of the Surveys was one quarter what it now is. Although,
erefore, it is unable to cope with the enormous progress made by the
ecutives as above shown, yet it manages, under the excellent Superin-
dence of Mr. H. M. Smith, to turn out a vast deal of very highly
ditable work, and to meet the most pressing of the wants of this large
esidency, as respects our regular Survey Maps, as well as to execute a
ge amount of miscellaneous desultory work sent to this Department

from the various Secretariats, to illustrate the Official Reports published by the several Governments

The following Abstract of the extent and estimated value of the Lithographic work executed, may serve to show in a measure what has been effected by this branch of the Department during the three years, from 1st January 1859, to the 31st December 1861 —

Description of work Lithographed	Number of Impressions or Sheets struck off	Cost of the Transfer Drawings	Cost of the Printing	Total actual Cost	Value or selling price of Maps	Difference to credit of the Department
		RS	RS	RS	RS	RS
382 Maps and Plans,	214,397	37,077	37,077	72,958	1,13,565	40,607

The value of this appendage to the Office can scarcely be over-estimated By the power of supervising the reproduction of the Maps of the Department, as they pass through the Press, great advantages are afforded, and the utmost accuracy ensured in the publication of the Maps The general style and execution of the Maps now turned out has been well exemplified on the lithographed Atlas of the Degree Sheets of the Himalaya Topographical Survey, which I had the satisfaction of submitting for the inspection of the Government, and which elicited the commendations of the Government of India and of the Secretary of State These intricate and elaborate Maps on the scale of four miles to the inch, delineating this most difficult mass of mountainous country, were executed in the style of Chromo-Lithography, each plate having four printings and by a combination of Chalk Drawing for the Hills, direct on the stone, with transfer drawing for the outline, writing, and figures, a very successful result was produced, which has been much admired by scientific men generally A copy of the same Atlas sent to the Great Exhibition of England, through the Calcutta Committee, obtained for the Department the honor of a prize medal, which I hope will be a further incentive to exertion towards effecting still greater improvements in the beautiful art of printing from the stone, and to which my anxious attention is constantly devoted

Copper Plate Engraving —As yet engraving on copper has not been practised in this Department, because the final Maps are under the old orders of the late Court of Directors, forwarded to the India Office, and

are there incorporated into the Great Atlas of India, the sheets of which appear periodically, as before stated, and it forms the special business of the Geographer to the Secretary of State to bring out these engraved Maps, but it would in my opinion be very desirable to attempt engraving on copper here, because there are many Maps and Plans, as well as Charts, of the Trigonometrical Survey, which it is most important to retain, with a view of printing fresh editions whenever wanted. With our Lithographs, the most elaborate Map, which may have taken months to transfer to the stone, is obliged to be cleaned off, to make room for other important work, the stock and material of the Office being altogether inadequate to its growing wants. The Natives of India, moreover, are susceptible of being made excellent engravers, and this description of work, I believe, could soon be effected much cheaper than in England. I propose, therefore, with the approval of Government, to add a Copper Plate Engraving Press to the Office, and to commence to put some of our more important Maps on copper, the plates of which can be kept so conveniently, and impressions struck from them as required.

Reproduction of Maps by Photography.—The great success which has attended the reduction and reproduction of Maps by the Photographic process in England, at the Ordnance Survey Office at Southampton, under Sir Henry James, and the transmission, for the use of this Department, of two fine cameras specially selected for the purpose, with complete sets of Photographic apparatus, by the Secretary of State, induced me to apply for two Sappers trained in the Southampton Office, to be sent out, to assist in this work. Two Sappers, accordingly arrived from England on the 1st June last, and joined this Office, on a salary of Rs. 100 per mensem each, to cover all demands, including their Military pay and allowances as soldiers.

None of the Maps hitherto produced having been drawn with special reference to the requirements of Photography, and all being highly colored, the attention of the Sappers has been directed chiefly towards the reproduction on the same scale, of certain Maps of Districts long since surveyed, but still unpublished. Various experiments have been made and are still going on, but much remains to be done to turn the labors of the Photographers to a good practical account. The rainy season has been much against them, and the want of a proper glass house and various other necessaries, including competent super-

intendence for carrying on work of this description, militates against rapid success The chromo-carbon prints transferred to zinc or stone have not been at all successful, and such manipulation, although well adapted to ancient manuscripts or old printed records, I believe is a very long way from adaptation to our wants for fine and large Maps Photography, to be carried out successfully as a system for a large and wide-spread Department, must be prosecuted under officers who have ample time to devote to it The Manuscript Maps, of course, must be prepared by Executives, strictly in conformity with Photographic requirements, and in this there will be no difficulty

The Anastatic Process—The development of the Anastatic Process for the retransfer of old Prints, Drawings, or Maps, to the stone or zinc, by immersion in solutions of strontia and nitric acid, has of late been successfully applied in England, and with the highly important advantage of preserving the original unhurt The employment of the Anastatic Press in India is likely to afford great facilities for reproducing those Lithographed Maps which have been long out of print, and of those parts of India which cannot be as yet engraved for want of correct Surveys, much has yet to be done in India in the above way, but I hope we are in a fair way towards keeping pace with all such-like modern improvements

No. XLIX.

BLASTING ON THE LAHORE AND PESHAWUR ROAD

An Account of the Blasting Operations undertaken for the removal of a portion of the Khoond Spur, on the new line of road from Lahore to Peshawur By Lieut.* A Taylor, R E, *Exec. Engineer*

Murree, July 1852

The old road from Attock to Peshawur, after crossing the Indus, runs for above three miles through a range of low but rocky and precipitous hills. This part of it is exceedingly narrow in many places, little over 10 feet, and some of the principal ascents are as steep as 1 in 8. It is known as the Gidar Galli pass

The right bank of the Cabul river was selected for the new line The only great obstruction on it was a cliff of limestone rock, near the village of Khoond, that jutted abruptly into the river The height of this cliff above the cold weather level of the Cabul river is 145 feet Its total length on the river face is 1,033 feet Of this length only 285 feet presented any extraordinary difficulty, the slope of the remainder of the hill, taken at right angles to the river face, was comparatively gentle, being in some places nearly $1\frac{1}{2}$ of base to 1 of height

The following account refers merely to the plan adopted for removing the precipitous cliff of limestone rock, 285 feet in length

Two sets of sections are given in the accompanying sheet of drawing The first set show the section of the hill when work was commenced, and the present section, the second set show the section of the hill before and after the explosion

On the 3rd June, 1850, the level of the road having been approximately fixed, the first and second Companies of Sappers commenced work by opening a path round the hill on the intended level, sickness prevented

* Now Lieutenant Colonel and C B

me from visiting the work again till October, when I found that having finished the path by the end of August, the Officer Commanding the Sapper Companies, in the absence of a liberal supply of blasting powder, had applied his men at the top of the hill to cut it down by manual labor, assisted by small blasts of powder when the rock would not yield to ordinary tools

Under this arrangement the execution of the work would have required an extravagant length of line, and the economy of the measure was doubtful, it was consequently determined to break up the cliff by four large charges of powder, placed as shown in the drawing It was expected that these mines would throw a considerable portion of the upper edge of the cliff into the river, and that what remained would be so broken up as to be easily wheeled over the edge of the road without further use of powder

By the beginning of November, 1850, the two horizontal galleries into the face of the cliff were fairly commenced No 2, measuring with returns, 100 5 feet in length, was completed on the 25th of January, 1851 No 1, 97 0 feet in length, was completed on 15th March, 1851.

The loading of the mines was commenced on the 21st March, 1851, at one o'clock, P M, the tamping was completed by eight o'clock, A M, on the 22nd, and all four mines were exploded simultaneously during the course of the day

The effect of the explosion was, to precipitate into the river the outer edge of the hill, (see shaded part, *Fig* 3,) and to break up the whole of the rock included between the dotted lines in *Fig* 3 Since the mines were fired, working parties have been employed in wheeling the *debris* into the river, and little powder has been used except on the base of the hill, at the level of the road, which was not much affected by the large quantity of powder exploded immediately above it

Lieutenant Watson, of the Engineers, was the Senior Officer with the detachment of the Sappers employed on this work Ill health, however, confined him to Attock through nearly the whole of the operations, and the real charge and direction of the works rested with Lieutenant Henderson, Engineers

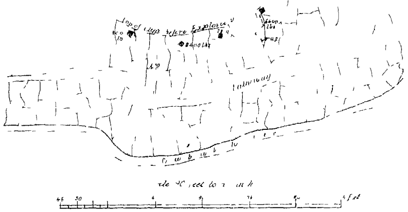
The following detail may be of use in future works of this nature

To avoid any chance that might exist of injuring, by the explosion, that part of the rock on which the road was to be carried, it was consi-

BLASTING ON THE LAHORE AND PESHAWUR ROAD

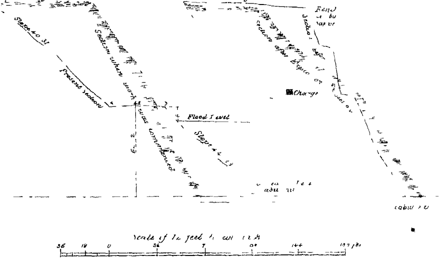
Plan

Fig 1



Sections

Fig 2 Fig 3



dered advisable to lodge the powder some few feet *above* the proposed level of the road, one gallery was accordingly commenced about 4 feet above the foot path, and carried in horizontally, the other was commenced at the level of the path and was carried in with a slight rise

This care appears to have been unnecessary, as in removing the *debris*, the rock immediately below the charges was found comparatively strong and uninjured

The *galleries* were tunnels into the solid rock, timber framing to support the roof was not found necessary

The main galleries were $4\frac{1}{2}$ feet high and 4 feet broad The branches were smaller, 4 feet by $3\frac{1}{2}$ feet The tunnelling was effected entirely by blasting with a small jumper of $1\frac{1}{2}$ inches diameter and from 3 to 4 feet in length, worked by two sepoys sitting The easiest way of working is no doubt to make the first blast at the top of the gallery, and to remove all stone that may be loosened by it The subsequent blasts should then be arranged as to blow through into this opening In driving these galleries the sappers were told off into four reliefs, and the work proceeded without check, day and night

In December, during which month the works were in full progress, each gallery was advanced 32 5 feet, being at the rate of a little more than 1 foot per working day of 24 hours The total number of feet of gallery driven was 130, 358 lbs of powder were expended in 176 blasts, varying in depth from 1 to 3 feet The *cost* of driving a gallery may be estimated therefore per foot, as follows, including the cost of tools

16 sappers in four reliefs of 4 men each, equivalent to about

10 coolies, @ Rs. 0-2 6,	Rs	1	9	0
2 6 lbs powder,	„	0	3	11
Repairs of tools, &c,	„	0	3	1
Total per foot of gallery,	„	2	0	0

Speaking generally, we found that a vertical shaft could be driven twice as fast as a horizontal gallery, the area of the section of excavation being the same in each Two of the *chambers* were worked exactly to contain the charges The other two were formed so as to leave a space round the powder, but we are unable of our own experience to say which is the better construction

Loading, Tamping and Firing —The powder was stored in the maga-

zine in camp in bags, made of a cotton stuff, holding each 10 lbs These were counted as they entered the mine The hose was 1 inch in diameter filled with coarse native powder It was prepared in the magazine in lengths of 50 feet, an arrangement which facilitated the measuring out of the hoses to the different chambers It was protected in the galleries by a thin wooden casing, about one-third of an inch in thickness The powder having been carefully lodged in the chamber, the end of the hose was introduced into the centre of the pile, conducted down to the floor of the chamber, thence placed in its wooden case, and laid along one side of the gallery, a thin wall of bags filled with clay and *debris* of rock was built at the end of the gallery to isolate the powder, and the floor of the gallery was then covered with 6 to 9 inches of *debris* to protect the hose Till this was done, work went on in the dark, afterwards lanterns were freely used A common candle in a lantern in No 1 gallery, not more than 40 feet from the mouth would not burn It was very warm in the gallery, but the men working in it experienced no other inconvenience As the want of light delayed the work considerably, a common thermantidote was applied to the mouth of the gallery It had the desired effect, and while it continued to be worked the lantern burnt freely.

In No 2 gallery, the candle burnt without the assistance of a thermantidote, which was probably owing to this gallery being somewhat more roomy than No 1 The lodging of the powder was commenced at 1 P M on the 21st, and the tamping was completed at 7 A M on the 22nd, total 18 hours, being at the rate of $5\frac{1}{2}$ feet per hour in each gallery The working party was 36 sepoys, relieved three times in parties of 18, aided by 100 coolies, who worked from first to last

The tamping having been completed, and the hoses all made of the same length, their ends were collected, attached to a piece of port fire, and covered to a depth of some inches with earth The result was perfectly satisfactory. The hoses, about 135 feet each in length, burned so evenly, that all four mines exploded together, there being scarcely a perceptible interval between them

Before firing the large mines, a number of smaller ones were exploded with Lines of Least Resistance of from 20 feet downward The charges of some had been calculated at $\frac{(L\ L\ R)^3}{10}$, some at $\frac{(L\ L\ R)^3}{15}$, generally we found the charges calculated at $\frac{(L\ L\ R)^3}{10}$ unnecessarily violent in their

effect, while $\frac{(L\ L\ R)^3}{15}$ gave charges somewhat too weak $\frac{(L\ L\ R)^3}{10}$ was adopted for the large mines whose Lines of Least Resistance were, respectively, commencing at No 1, 30 feet, 40 feet, 30 feet, 40 feet, and their charges 6,400 lbs, 2,800 lbs, 6,400 lbs, 2,800 lbs, total 18,400 lbs

Powder —The greatest part of the powder used was made by Lieut Henderson, the materials having been procured in the neighbourhood of Attock, its average cost was Rs 7-8 annas per maund of 80 lbs

The Khoond Spur is of hard closely packed limestone The total number of cubic feet of rock removed in the cutting is about 2,000,000 of which 1,840,000 cubic feet were effectually reduced to *debris* by the large mines, being at the rate of 100 cubic feet of rock per pound of powder

A TAYLOR, LIEUT, R E

No. L

ALLAHABAD SPECIFICATIONS

(2ND ARTICLE)

[The following extracts are taken from a very useful book of Specifications, Rates, Contracts, &c, prepared for use in the 2nd Circle, N W Provinces, by Capt F W Peile, R E, Superintending Engineer]

PLASTERING

In executing plastered and pointed work, the joints of the masonry to be raked out and cleaned

In executing lime plaster, the joints to be stopped with mortar, and the plaster floated on in layers of such thickness as may be directed, well and slowly worked to a smooth and proper face, free from all blemishes and blisters

Exterior lime plaster, that is, where exposed to the action of the weather, will consist of 45 parts of the best kunkur lime, 45 parts of fine soorkhee, and 10 parts stone lime When laid on a *floor or terrace roof*, the plaster to be beaten till quite set and hard, and to be finished with a thin float of stone lime well rubbed in with the floating board

Interior lime plaster, where not exposed to the weather, to consist of equal parts of kunkur lime and soorkhee

Sand plaster to consist of equal parts of loam and sand, floated on and brought to an even surface

All mouldings to be worked true to a template, and, if required, cow hair or chopped hemp to be added to the material to strengthen it

Where plaster is to be laid on in successive layers, the lower must not be allowed to dry, and the surface must be freely scored with the trowel before receiving the second coat

In executing flat joint pointing, the joints to be stopped with mortar, consisting of equal parts of kunkur lime and soorkhee, finished off flush and clean with the face of the brick-work

In executing tuck pointing the joints to be stopped as above, and a band of fine plaster or putty of stone-lime sieved and cleaned, to be raised over the joint with parallel edges

THATCHER'S WORK

Grassing—The several descriptions of grass roofs are to be well and closely tied, laid in one, two, or three layers according to circumstances, and in such manner as the Executive Engineer may direct

The quantity of grass, bamboos, and string to be used will in a measure depend on the description of each procurable in the market

Grass bundles of the ordinary size of Gurrur grass, from 100 to 150 bundles per inch of thickness, per 100 superficial feet of roofing, will be required, and about 25 bamboos (ordinary Pillibheet) and 3½ seers string (*ban*) to each layer of the coating

The grassing of a roof will not be considered properly executed if it sink more than one-eighth of its thickness with the weight of a man standing on it

Where the thickness of grassing is to exceed 8 inches when finished, it will be laid on in three layers, the first not exceeding one-third of the whole thickness, may, if ordered by the Executive Engineer, be of *surput* or *khassa*, or other reed or coarse grass, and it may be in the first instance laid loose on the roof and tied tightly down with battens not more than 9 inches asunder, the ties at not greater intervals than 9 inches The second and third coats to be always of Gurrur grass made up into tatties on the ground, each of thickness sufficient to form one-third of the finished coating, the grass closely packed and tied with two battens below and two above, with ties at intervals not greater than 18 inches, each layer of tatties to be separately laid and tied on the roof with ties at not greater intervals than 9 inches. The whole surface of the finished roof to lie evenly without rises or hollows

Where the thickness of grassing is to be less than 8 inches, it may be laid on in two layers, both will be of Gurrur grass laid as specified for the upper two layers above.

The eave bundles are to be of the full thickness of the grass coating evenly and tightly laid, cut off squarely and neatly, and perfectly straight.

Where the renewal of top coat has to be executed, the old top coat will be entirely removed. All hollows will be made up evenly with fresh grass laid under the battens of the lower coat, to which new ties wherever required will be given, and the top coat of new grass will then be laid on as above.

Bamboo Frames.—The bamboo work of a roof may consist of the ordinary frame, tied with *ban*, and laid over the rafters, or of a similar frame nailed to the rafters without ties, or of whole or split bamboos laid at intervals, or touching each other and nailed to the rafters.

Class I.—Will consist of medium-sized bamboos (averaging 20 feet long and 2½ inches diameter at the butt) laid longitudinally 9 inches from centre to centre, butts reversed alternately, with small bamboos (Pillibheet or Mirzapore) split in two, crossing them at intervals of 3 inches from centre to centre, and all nailed down to the roofing timbers, and to each other.

Class II.—Will consist of medium bamboos split in two, and nailed down to the roofing timbers, at intervals of 5 inches from centre to centre.

Class III.—Of small bamboos whole, touching one another, and nailed down to the roofing timbers.

Class IV.—Of medium bamboos laid as in Class I. and with small bamboos split in two, one-half laid below and one above, crossing them either at right angles or diagonally at intervals of 3 inches from centre to centre, with a *ban* tie at every intersection.

Class V.—As above, but the small split bamboos laid on one side only.

Class VI.—Small bamboos laid longitudinally at 9 inches intervals, and diagonally crossed on one side with two layers of split bamboo battens, and the sides of the frame secured with split bamboos on all four edges. This sort of frame generally used to close a doorway or form a partition.

Newly cut bamboos are not to be used, as they are liable to weevil (*goon*)

Wherever nails are used, the nail holes must invariably be drilled through the bamboos

Bamboo Purlins, of large bamboos, averaging 27 to 30 feet long, and not less than $3\frac{1}{2}$ to 4 inches diameter at the butt, may be spiked or tied down to the rafters of a building instead of sawn scantlings Any portion of the bamboo that may be less than 2 inches diameter to be cut off and rejected The spikes used to be not less than $2\frac{1}{2}$ inches longer than the thickness of that part of the bamboo through which they have to be driven.

Where mats are laid over a bamboo frame-work, they will be laid with their edges overlapping and tied down by battens of split bamboo, so laid that in no place shall one superficial foot of matting be left without its batten

Sirkee Ceilings.—Sirkee or reed mats will be put up as ceilings of verandahs, and in other positions, they are to be laid overlapping in such a manner that the reed only and none of the grass head may be exposed, and so tied up with thin bamboo battens and hemp string (*sootlee*), that the upper mat may always entirely conceal the batten of the one below The butts of the reeds are to be arranged in straight horizontal lines

Fire-Ladders are of two kinds—bamboo and rope

The bamboo ladders are intended to reach to the eaves of thatched buildings, they are from 10 to 12 feet long and 18 inches wide between the rails The side rails, of large sound bamboos connected at top and bottom by a piece of half-inch rod iron passing through both, with a shoulder welded on to prevent the bamboos closing, and rivetted over a washer on the outside to prevent them spreading An iron band is shrunk on to both ends of each rail The rungs, of large bamboos split in two, lashed with tarred lashing line, at intervals of 15 inches to the side rails

The rope ladders are fixed to the ridge, and lie on the slope of the roof to the eave The side ropes are of closely laid 3 inches (circumference) hemp rope tarred, and the rungs are of pieces of small bamboo, 2 feet long, passed through the strands, and lashed with line to the side ropes at two feet intervals.

The side ropes may in some cases for the sake of economy be made of *moonj*

Tiler's Work

Flat square tiles for floors and roofs to be 12 inches square, and 1 inch or $1\frac{1}{2}$ inch thickness , made of well-tempered clay, thoroughly burnt, not vitrified, without flaws or twists, sound, of regular shape, with sharp square edges, and ringing well, to be laid with a close joint of not more than three-sixteenths of an inch in thickness, in mortar as for second class brick-work

Where more than one course is laid, they are to break joint, and have not less than half an inch thickness of mortar between them

Goodwyn tiles of the form shown, and laid in the manner exhibited, in (see *ante*, Plate XV)

Ventilating, cylindrical and pantile roof —Atkinson's pattern consists of two layers of tiles, the upper being Italian pantiles, laid in cement over cylindrical tiles

(*a*) The cylindrical tiles to be 12 inches long, 4 inches external diameter, and half inch thick, fitting one half inch into each other, with a shoulder and socket joint, a lip, to rest on the timbering, to be raised on at half an inch from the shoulder , two holes, of half inch diameter each, to be pierced through the tile in line with the lip which is on the lower side of the tile The tiles to be moulded of well-tempered clay, thoroughly burnt, sound, and of true shape, without taper

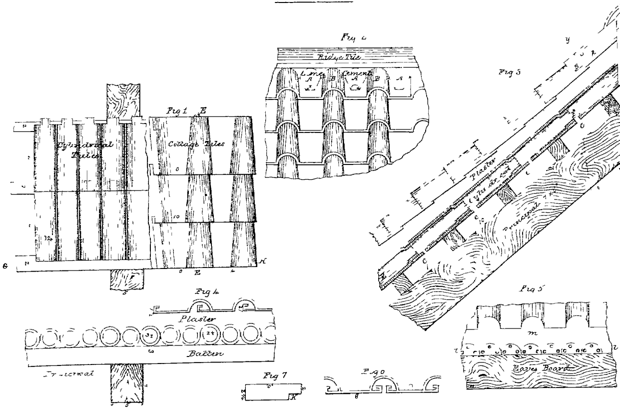
(*b*) These cylindrical tiles being laid close, with their axes up the slope of the roof, are to be covered with coarse mortar or fine concrete to a depth of one inch, and in this, while still wet, will be laid Italian pantiles

(*c.*) The pantiles are to be 12 inches long and 12 inches wide over all, and not less than half an inch thick, moulded of well-tempered clay, and thoroughly burnt, free from twists, sound and firm, and all of uniform size and shape

(*d*) The mortar in which the tiles are laid is to be drawn up, so as to fill the curved roll which overlaps at the vertical joint

(*e*) The lower edge of each pantile to overlap 3 inches the tile below it A lip to be raised on the under side of each tile to rest against the lower tile and prevent slipping

ATKINSON'S TILED ROOFING



The Italian pantiles above described will sometimes be set in mortar, without the layer of cylindrical tiles In this case the rate to include the mortar setting, which will vary in thickness according to circumstances

Ordinary country half round and flat tiles (*nurriah* and *khaprah*) will be laid in mortar or dry, according to circumstances The tiles to be not less than 10 inches long, made of well-tempered clay, thoroughly burnt, and sound

---

WELLS AND FOUNDATIONS

Well-sinking —In wells lined with brick-work steanings, the excavation will be carried down to the spring level, before the curb is laid and steaning built up

It occasionally happens that the sinking of steaning cannot progress on account of the interposition of a bed of kunkur, or hard soil, below which a sufficient supply of water would be found In this case, it may be necessary to underpin the curb. This is done by cutting away a portion (say one-sixth inch) of the diameter from beneath, and filling up the void carefully with masonry, then cutting and filling another section, and so on until the whole ring is complete

But if the soil is very firm, or the curb rest on a bed of block kunkur, it would be better not to carry the steaning through, but merely to pierce the bed with a shaft of two feet less diameter than the diameter of the well

A large supply of water may be frequently obtained by carrying the steaning to a moderate depth below spring level, and then boring a 6-inch augur hole down the centre to a depth of 20 or 25 feet further If an iron cylinder be passed down and left in this shaft, with its top projecting three or four feet above the bottom of well to prevent its being choked, success will be certain

(*a*) *Specification* —For a well of 6 feet interior diameter and 2 feet thickness of steaning

(*b*) The excavation to be carried down to spring levels, 50 feet below the surface of the ground, 12 feet in diameter

(*c*) A stratum of sand 8 feet thick lies 10 feet below the surface,

in order to prevent the sides falling in, the excavation will be carried through to the bottom of the sand stratum with a diameter of 20 feet

(*d*) If in the progress of work it be found that the sand is likely to give way, a dry brick-work steaning $1\frac{1}{2}$ bricks thick will be built up to support it to the full depth of the stratum, with a clear interior diameter of 17 feet This steaning will rest on the step left at the level where the diameter decreases to 12 feet It will be taken up again when the well steaning has been sunk to its proper depth

(*e*) When the excavation has been carried to the required depth (50 feet) the sole will be brought to a true level and the curb will be laid in

(*f*) The curb will consist of two thicknesses of *Jamoon* wood dovetailed, secured with iron straps and bolts, and put together with wooden dowels and treenails as shown in the drawing To be closely and neatly framed and finished in a workman-like manner The upper thickness of 2 concentric rings, each of 6 parts and 12 inches wide, the lower of one ring 2 feet wide in six equal parts, all laid so as to break joint with one another If timber cannot be found of width sufficient to make the lower of one ring, this will be divided as shown in the Section at A, into two rings of 15 inches, and 9 inches, respectively

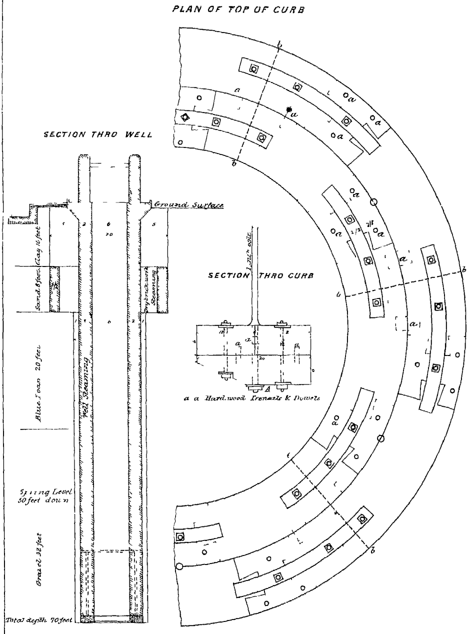
(*g*) To the curb and bolted through its depth with nuts below will be fixed six stanchions of 1-inch bolt iron, 10 feet long, which will stand at equal distances around and in the centre of the ring of the curb The masonry of the steaning will be built up round these, and they will be connected together at the height of $9\frac{3}{4}$ feet by a ring of flat bar iron $2\frac{1}{2} \times \frac{3}{8}$, lying flat on the brick-work, through which holes will be punched to receive the ends of the bolts, and on which washers and nuts will then be securely screwed down.

(*h*) The brick-work will be executed with the best fully burnt bricks, the headers moulded to taper $9\frac{1}{2}$ inches long, 4 and 5 inches at the ends, and $2\frac{1}{2}$ thick, the stretchers without taper $9\frac{1}{2} \times 4\frac{1}{2} \times 2\frac{1}{2}$

(*i*) The bond will be as follows —

In the first course a row of stretchers will be laid round the inside of the ring, and on the outside two concentric rings of headers, in the second course the row of stretchers will be laid on the outside and the two concentric rings of headers to the inside The courses will alternate in this way throughout the work.

WELL AND CURB



Scale 16 feet - 1 inch *Scale 1½ feet - 1 inch*

b b The thick dotted lines give position of the middle of junctions of parts of lower ring

(j) No vertical joint on the interior of the steaning to be wider than one-eighth inch, no course joint to be wider than $3\frac{3}{8}$ inch.

(k) The cement below water line to be of hydraulic lime. All cement to be ground and mixed under edge stones.

When the steaning has been built to a height of 30 feet, it will be left for 30 days to dry, and the sinking will then commence.

(l) When the steaning has been sunk, 10 feet of brick-work will be added to the top. It will then be sunk 10 feet further, making a total depth of 70 feet, at which it is expected that the supply of water will be sufficient. The steaning will however be carried down until four bullock motes, working continuously for 24 hours, fail to exhaust the water.

(m) When sunk to this depth the soil will be carefully removed from under the curb until it has an even bearing all round. The brick-work will then be brought up to within 2 feet of the surface from which height it will be corbelled out, course by course, $2\frac{1}{2}$ inches in each course, to the outside for 10 courses, until the total breadth of the ring amounts to 4 feet. Four courses will then be added of this breadth, and the well will be finished off with pillars and cistern as shown in the drawing.

(n) The cistern will not be built over the excavation, but will be founded on the undisturbed soil, and be connected with the well platform by a stone channel.

(o) The space around the steaning will be filled in with dry rubbish below and earth above carefully rammed.

(p) The brick-work below the water line on the inside will be flat joint pointed, thence to within 4 feet of the top, it will be carefully tuck-pointed, the remainder with the platform, pillars, cistern, &c., will be carefully finished with the best lime plaster.

The above Specification will apply to sinking Wells for Foundations with the following additions —

(a) A plate of $\frac{3}{8}$-inch sheet iron to be put on round the outside of the curb projecting two inches above the top, to hold the brick-work, and two inches below to form a cutting edge.

(b) The whole of the masonry to be flat joint, pointed on the inside, and carefully plastered on the outside, to reduce the friction in sinking.

Specification for Cofferdam for laying in the foundations of the Seotee Bridge of the Great Deccan Road (given as a guide)

(*a*) This bridge, which is to be of 5 openings of 40 feet span, is to be constructed across the Seotee River at Drummondgunge The site of the bridge is fixed within very close limits by the completed road and the position of the Pass at Kutra over the lower Kymore range, which is about half a mile distant

(*b*) Half a mile above the site of the bridge the bed of the river consists entirely of sand-stone rock, which is considerably broken up and thrown about in masses At site the bed, to a depth of four feet, is of sand and *budgeree*, lying on a stratum of blue loam, of density and tenacity gradually increasing with the depth At 10 feet the soil is firm and tenacious and can be trusted The dry weather stream is about 12 inches deep

(*c*) The reason for selecting cofferdam, instead of well or block foundations in this case, is the high probability of meeting with large boulder stones or slates of the sand-stone rock from up-stream, bedded at a depth below the surface, which would interfere greatly with the sinkage of the blocks, and probably altogether frustrate any attempt at obtaining a secure foundation by those means

The nature of the substratum, moreover, while it affords facilities for the construction of a cofferdam, would cause much labor to the well-sinker

(*d*) The cofferdam will consist of a single line of sheet-piling driven and secured as hereafter shown for the foundation of one of the piers.

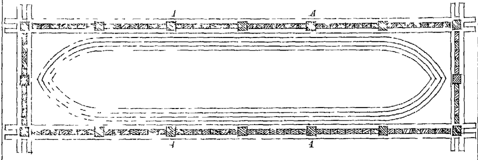
(*e*) The timber for the piles to be of sál wood, to be carefully selected, straight-grained, free from knots and ring shakes

(*f*) The gauge piles alone will be rung with an iron hoop $3 \times \frac{1}{2}$ inches, these will also be shod with cast-iron shoes of the form shown in the diagram, with a square abutment for the pile to rest on

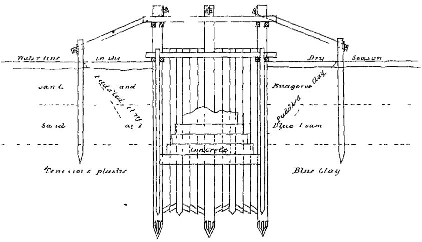
(*g*) The sheeting piles will not be shod, but the end will be cut with an inclined edge to give the pile a drift towards the next pile. The sheeting piles will all be carefully fitted to each other before driving to ensure close contact

COFFERDAM

GROUND PLAN



CROSS SECTION



Scale 10 feet = One inch

(*h*) The wedge piles will be tapered 2 inches in a regular taper for the lower 6 feet, the side of the upper 9 feet being left parallel.

(*i*) The space to be inclosed is in the clear 43 × 10 feet within the sheeting Each long side will be divided into 6 equal bays, 6 feet 5 inches long each, and each end into 2 bays of 4 feet 5 inches each, by gauge piles 9 inches square, driven 17 feet below the water line, and standing 5 feet 6 inches above it

(*j*) The sheet piles will all be 9 inches by 4 inches, and driven 15 feet below the water line, with their heads $1\frac{1}{4}$ feet above the water line

(*k*) When the gauge piles are driven to their proper depth, two rows of temporary double walings 6 inches by 4 inches, will be bolted on, the upper one to be 4 feet above the water line, and the other as low as it can be fixed, but not within four feet of the upper The wales will be fixed to the gauge piles by $\frac{3}{4}$-inch iron bolts and nuts

(*l*) The sheet pile to fill up the bays are to be driven truly, and each bay keyed in with a wedge pile to make the dam water-tight

(*m*) When the piles are all driven, behind each gauge pile and at eight feet distance from it, on the outside, a pile 6 × 6 inches will be driven 10 feet, its head standing $1\frac{1}{2}$ feet above the water line Through mortices in the head of this and of its corresponding gauge pile, a piece of $2\frac{1}{2} \times \frac{5}{8}$ inches flat bar iron will be passed, through slots in which wedge keys will be driven, against iron plates laid against the piles

(*n*) A shore of timber 6 × 6 inches will be laid across between the heads of the pairs of gauge piles AA, on each side of the centre of the dam

(*o*) The excavation will then be commenced, and having cleared 5 feet, the upper row of wales will be taken off and fixed at that depth against the inside of the dam, spurred and strutted across to add to its stiffness

(*p*) As the excavation proceeds the water will be baled out, and the seams between the piles will be well caulked and payed with oakum and tar

(*q*) Simultaneously with the interior excavation, and carried on with it to equal depths, the soil will be removed from the outside to as great a depth within a limit of 10 feet below water line as possible.

This will be filled with puddled clay. It is expected that if the exterior can be thus cleared to a depth of 7 feet below water, there will be no difficulty in laying the interior of the dam nearly dry

(*r*) When the interior excavation has reached 10 feet below the water line, and been brought to a level, a bed of concrete 12 inches thick will be carefully laid in, the dam having been previously permitted to fill with water The concrete will be carefully lowered in baskets, and be brought to a level on its surface This will be allowed to lie undisturbed until thoroughly set, which should occur in 20 days, when the water will be thrown out, and the construction of the foundation proceed in stone laid in cement

(*s*) As the masonry rises, good strong clay will be rammed in round the work, so as completely to fill the space between the dam and the pier

(*t*) As there would be danger of disturbing the bed by drawing the piles, they will be cut off on completion of the work at 6 inches below the water line

Concrete Works —As a rule, the lime by itself will be slaked and saturated with water till brought to the consistency of a thick paste The other materials will be thoroughly mixed and saturated with water by themselves, and the lime will then be added and the whole thoroughly mixed when the concrete will be laid in—not thrown into the trench.

No more material to be mixed than can be laid on the same day

The surface of the concrete unless under water, to be generally rammed with flat rammers and watered till cracks cease to appear.

The bed to be laid in one depth or in successive beds as may be directed by the Executive Engineer, but one bed always to be finished off throughout the surface before the second is commenced.

If laid under water, the concrete may have to be lowered in baskets, sacks or boxes

A good concrete may be made of the following proportions —

	Parts.
Broken stone, kunkur or vitrified brick, 1 and 2 inch gauge, ...	65
Soorkhee (pounded brick) or clean sharp sand, ...	21
Good pure lime, ...	14

The lime must be of the very best quality in this case. 100 cubic feet of these materials will yield only 80 cubic feet of concrete.

Sand should be preferred to soorkhee if there be saltpetre in the soil If the concrete be laid under water, the lime must be hydraulic

---

Concrete under flags in flooring will generally have to be made with fine ballast material, and a large proportion of lime

Khoa work in roofs will generally consist of 50 parts brick broken to one inch gauge, 30 of coarse soorkhee screenings, and 20 of kunkur lime, laid on and beaten till perfectly hard and set, and kept watered until the coat of plaster is put on Staunching to arches and walls will be similarly applied Lime screenings are not to be used as ballast in khoa work.

Correspondence.

THE Editor acknowledges, with thanks, the receipt of the following Papers :—Jubbulpore Railway Specifications—Roorkee Iron Roofs—Madras C. E. College—Design for a Barrack—Kooium Frontier Outpost—Oil Mills for the E. I. Railway—Sutlej Canal Report—Indus Tunnel Project—Attock Suspension Bridge—Ventilation of Barracks and Jails—Indus Silt Experiments—Purtapore Stone Quarries.

Dalhousie, 15th September, 1864.

TO THE EDITOR.—If you and your readers have not had too much already of "Striking Centres with Sand," I should like to add a few remarks. The centres of nearly all the arches of Bridges on the Baree Doab Canal, exceeding 20 feet in span, having been struck in that manner, some practical experience in the process has been gained.

It is strange that none of your Correspondents appear to have observed in the "Civil Engineer and Architect's Journal" for 1857, Vol. XX., p. 116, the extract from the abstract of Captain Fowke's Report to the President of the Board of Trade on the Paris Universal Exhibition of 1855. Captain Fowke gives M. Bouziat, the inventor's own account of the process, and to save trouble I annex a copy of the extract.

It was on seeing this extract that I adopted the process on the Baree Doab Canal.

You will observe that from not having seen M. Bouziat's description of his invention, several of your correspondents have had the trouble of experimenting on their own account, and have not yet arrived at the simple elegance of the original. For instance, as pointed out by Mr. Spencer in your No. IV., the omission of a shelf or platform on which the semi cone of sand may form outside the hole, destroys the self-acting portion of the process, the most beautiful part of the whole invention, the gradual step by step descent of the centres held in perfect control the while, and regulated by the Engineer at his will. This arrangement is of the utmost utility, with flattish arches especially, say 50 feet span with a rise of 7.7 feet, in brick, the description of several of the arches on the Baree Doab Canal, as by lowering the haunches in advance of the crown all loading of haunches is rendered unnecessary, and the operation can be performed without the slightest crack showing.

Again, many of your correspondents appear to think it necessary to have a "box" for the sand, or a "bottom" to their cylinders. But this is not needful. An open cylinder of sheet iron is all that is required. Two or three sets of such cylinders (20

in each set) sufficed for the whole of the bridges of the Baree Doab Canal, whose arches were struck by this process in [illegible]-61, some 40 or 50 in number

The only practical difficulty I know of in the matter is the keeping the sand dry in the cylinders, especially if the arches are turned in wet weather and if some time elapses before the centres are struck An apron of tarpaulin securely attached all round the piston and which can be detached before striking keeps water from getting in above, and the sand is kept dry below by its being raised above the level of the platform on the circular piece of wood described by Captain Fowke

But if some of the sand does get a little moist, it can be raked and pushed out by the iron rod described by M Bonziat as the holes stand opposite one another For this reason the sloping holes represented by Mr Spencer are, I think to be avoided, as also the vertical central hole advocated by Colonel Scott

J H DYAS, CAPTAIN, R E

Correspondence.

THE Editor acknowledges with thanks the receipt of the following papers —Bombay General Hospital—Vaulted Roofs in Sindh—On the Expansion of Masonry by Heat—On Revetment Walls—Rangoon Custom House—Umritsur Clock Tower—Steamers for the Punjab Rivers—Allahabad Jail—Irrigation and Drainage of the Terai—Formulæ for Dimensions of Arched Bridges—Mean Meer Church—Markunda Bridge—Sehore Church

A correspondent writes from Central India —

" I notice in the Professional Papers for May, that in your Paper on Anglo-Indian Architecture, you write that good glazed tiles are made in the Punjab and elsewhere This is utterly unknown here, and is much wanted I should be much obliged if you would let me know where I could get information as to the preparation of the glaze and description or sketch of kiln required "

Glazed tiles are made, and can be procured at Delhi, Lahore, Peshawur, and Moultan , the best I have seen are at the last place , the ordinary colors are white, blue, and a brownish red At Delhi they ask for tiles of any size, 1 inch thick and from 6 to 12 inches square, 750 rupees per 1000 square feet The tile makers are very jealous of their trade secrets, and I am sorry I can give no details of the manufacture The glaze used is principally made of borax (*sohagah*)

Another correspondent says —

" I observe that in the Bengal Presidency it is considered necessary by Engineers Civil and Military, to sink wells for foundations to very considerable depths, generally this is done with a view to pass through the sandy bed and to reach the under-lying clay or rock

In the discussion which followed the reading at the Institution of Mechanical Engineers, of a Paper on Railway Bridge Pier Foundations, published in the " Civil Engineer and Architect's Journal," for December, 1863, I observe that Mr Strong asserts that the sand was far deeper than his foundation wells.* He bored through

* See *ante*, p 389

80 feet of nothing but sand, his wells were 43 feet deep, which is the depth, as he says, to which wells are generally sunk

"I beg to suggest for discussion the question whether these great depths are necessary

"Wells for foundations are I believe rarely or never sunk in Madras to any considerable depth I have looked over the plans given in the four vols of "Madras Engineer Professional Papers," and can only find one instance in which the wells were sunk so much as 10 feet, generally 6 or 8 feet are considered sufficient

"The principal object in my opinion is to take care that the wells are well bound together across the stream and into the banks, so as to prevent any displacement of the sand by currents passing between them

"In the case of bridges, if there are not retaining walls on wells and aprons, there is no resistance to the additional velocity caused by the obstruction of the bridges, a scour is produced along the piers, &c, and the sand is displaced to very great depths 40 feet, if I remember right, in the Jumna"

Δ

Δ's remarks are perfectly correct The following is an extract from a letter by Col Yule, the late Secretary to Government, on the same subject —

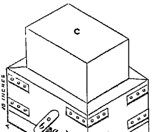
"Well foundations may be used in two ways, viz, either by employing the wells as piles and sinking them till we reach a firm stratum, or, where such a stratum lies very deep, by establishing a practically impermeable barrier under the bridge, in the shape of flooring and curtain walls, to secure the foundations from scour The last method has often been used, on this side of India (without, it is believed, a serious example of failure), but it has never been so fully taken advantage of as in the Madras Presidency There, well foundations of bridges in sandy beds of unknown depth, are not sunk more than 9 or 10 feet, often less, the wells themselves being also of very rough and crude structure Yet they stand safely, and it is mainly owing to the cheapness of this construction that so many noble bridges have been built in Madras Presidency, over rivers such as we habitually leave unbridged, on account of the estimated cost Indeed, the experience of Madras shows that well foundations of 6 feet in depth, on sandy river beds having a slope of 3½ feet per mile, are secure"

In accordance with this opinion, the foundations of the Markunda Bridge, now being constructed on the Grand Trunk Road near Umballa, (and which will be described in the next Number), are being sunk to a much less depth than is usual in Upper India, having a flooring between the piers protected by curtain walls in front and rear The same principle is also generally applied to Canal Bridges in these Provinces. But it is to be remembered—1st, That the fall in the beds

of these rivers is generally greater than in those of Southern India, while the soil is as bad, if not worse, 2nd, That it is a general practice in Madras rivers to protect the bed for a considerable distance down stream, by throwing in large quantities of loose rough stone, and that holes formed by scouring are thus filled up, often it is believed for some time continuously after the construction of the bridge, but that this superabundance of material is rarely available in these parts, 3rd, That the cost of the flooring and curtain walls would often not fall very short of the additional cost required to sink the well foundations an extra 15 or 20 feet —[ED]

The following letters refer to the Mode of Striking Centres by the use of Sand, described in Nos II and III —

Method of Lowering Centerings, as practiced on the Great Deccan Road Bridges —



"The centerings are struck by means of boxes containing fine dry sand These boxes are 16″ × 12″ × 10″ outside measurement, of 2-inch planking open at top, corners dovetailed and bound with hoop iron fixed with screw nails In each end of the box a hole, *a*, one inch square is cut near the bottom slanting upward from outside, over the hole, a stop, *b*, is fixed, turning on a pivot by means of which the hole, *a*, can be opened or closed as desired

"A solid block of wood, *c*, 12″ × 8″ × 8″ the exact size of inside of box, is placed on the top, supported by the sand inside the box, and sunk ½ or ¾ of an inch into the box The boxes complete are then supported either by masonry pillars or wooden strutlings, and the tops of the wooden blocks levelled by adjusting the quantity of sand in the box The support should be the same width as the box so as to allow the sand to run out freely when the stop is opened

"A beam 6″ × 8″ the full width of the arch is placed transversely, that is parallel to face of abutment, resting on the block of wood *c*, and on this beam the centering rests

"All joints of the box should then be well caulked to prevent water getting in when the arch masonry is in progress, and wetting the sand

"When the centre is to be struck the stops *b* have only to be moved uniformly to one side, which allows the sand to run out and the block *c* together with the whole of centering being unsupported by the sand, are lowered very gradually and to such extent as may be wished, being regulated to a nicety by the stop *c*

"I think this method preferable to that adopted by Captain Meade at the Moihun Bridge, in so far as the boxes are put in when the centering is erected, instead of first putting in a block of wood, which has to be struck out when the sand bags are inserted.

"I think the operation of striking out the blocks of wood, unless very carefully managed, must in itself lower the centering a little, and the danger of the lags splitting is also avoided"

J MACDONALD, C E

To the Editor

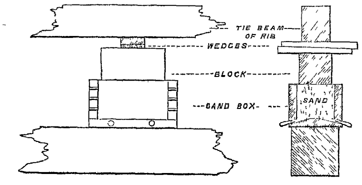
"*Striking Centres with sand* —The above subject having been mentioned in two of your Numbers, I am perhaps, rather late in offering a description of the method adopted on the Mirzapore district of the East Indian Railway, and which was found successful on repeated trials

"I should not now trouble you with these remarks, but that I believe my experience may be useful to some of your readers, and may save them from trying more complicated or expensive plans, which are not adapted to the nature of sand

"Many of the bridges on the Mirzapore district are built with ashlar arches of 60 feet span and of great weight, necessitating a very strong centering, this consisted generally of seven ribs of sal timber, carrying for laggins a layer of the sleepers afterwards used in the permanent way The ribs were kept vertical by being tied together with cross braces, and were supported with four pairs of wedges under each rib in the usual way

"The centering of our first arch was struck in the old way, a man with a sledge hammer was placed over each pair of wedges and at a given word they all struck together From that moment the noise of the hammers rendered any further order inaudible, and the wedges came out one after the other, in no particular order, according to their tightness or the strength of the hitting The result was most unfortunate, the heavy ribs came down singly, and in so doing broke from the cross ties, and ultimately fell over on their side and severely injured some of the hammer men

"It was this accident which caused the adoption of sand boxes, which were made in the following way —



"The box is made of 2" sál plank, 18" × 9" × 9" inside dimensions, the sides are dove-

tailed into the ends and the joints all secured with 5-inch screws, the top is left open Over this box and resting on the sand is a rectangular block measuring $16'' \times 8'' \times 8''$, so as to give half an inch play at each side and one inch at the ends At each side of the bottom of the box are a couple of $1''$ holes sloping upwards and inwards, and closed for the time with wooden plugs loosely driven in and luted round with a little moist clay

"When the arch is ready for striking, four of these boxes, (28 in all,) are placed under each rib as near as possible to the supporting wedges, the box is filled with dry sand, the block laid carefully on the sand so as to be clear of the inner edges of the box, and a pair of greased wedges with only 1 inch taper are driven with a hand hammer between the block and the tie beam of the rib The old wedges are then easily knocked out and the arch rests on the sand and is freed by drawing out the plugs

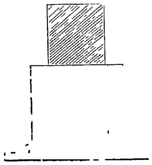
"The same set of boxes was used, for, I believe sixteen arches without receiving any material damage

"This construction of sand boxes may perhaps appear too simple to be worth describing, and the only feature to which I wish to draw attention is that the surface of the sand is left uncovered for half an inch all round the edges and shows no tendency to overflow, notwithstanding the enormous weight laid on it, it being the property of sand not to transmit lateral pressures beyond a certain angle

"The central surface of sand on which the block is laid forms such an unyielding bed that in transferring the weight of the arch and centering from the old wedges to the sand boxes, the greatest subsidence observed at the crown was never more than one eighth of an inch

"The play thus allowed to the block is essential to its steady descent, because as the sand is let out by the sides, its upper surface does not remain horizontal, and the block being no longer on a level bed would, if made to fit tight, most inevitably get jammed and stop or burst the box, any close fitting plug or piston will I think be found to fail on this account

"I would suggest the following modification of the above construction as applicable



to very large spans, or to any case where the arch requires to be let down slowly, or the process of lowering to be stopped at any point

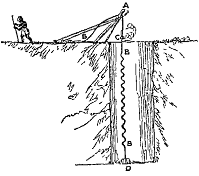
"Dispense with the plugs and let the box stand on a plank a foot wider than itself so as

another, which is sometimes advantageous [illegible]

C J SPENCER,

District Engineer, E I Railway

A coirespondent sends the following dodge for fiing a chaige in Wells oi Shafts



A A couple of bamboos tied

B No 8 telegiaph wie twisted iound a ciowbai till the iing iuns slowly but suiely

C A iing of the same wiie ¾ inch dia-meter

D Block of wood through which wiie is fastened

Round the iing twist cotton that has been soaked in a mild solution of gun-powdei, set it on fiie and let it iun down the wiie

H R

GLOSSARY OF INDIAN TERMS USED IN VOL I

Anicut —A weir of masonry built across the bed of a river to raise the surface level of the water for irrigation purposes It is a Madras term

Beegah —A local land measure, varying much in different districts, but usually about three-fifths of an acre

Bheestie —A Water-carrier

Bhoosa —Chopped straw

Bhuttee —A native kiln

Budgeree —Calcareous gravel used for mixing with lime

Bullah —A young tree is so called when felled and used in the rough for roofing, piling, &c

Bund —An embankment

Chokut.—The outer frame of a door or window

Chunam —Lime cement

Coolie.—A laborer

Deodar (*Cedrus Deodara*).—A valuable wood found in the Northern Himalayas, and used generally in the Punjab, nearly the same as the Cedar of Lebanon

Dhenkey —A lever worked by a man's weight, and used to draw water, pound bricks, &c

Doab —A tract of country between two rivers

Ghât.—1 A mountain pass. 2 A river landing place

Ghooting —A kind of lime

Grammie —A thatcher, he also makes common scaffolding and framework

Gunny —A kind of coarse sacking

Indian coinage —12 pies or 4 pice = one anna ($1\frac{1}{2}d$)
16 annas = one rupee ($2s$)

Jamah.—Vitrified brick, used for flooring, metalling, &c.

Jham.—The peculiar tool used in well sinking (*see* p. 378.)

Khureef (fusl).—The autumn crop, sugar, &c.

Kucha masonry, consists of sun-dried brick set in mud.

Kucha Pucka masonry.—Is of burnt brick set in mud.

Kunkur.—A peculiar kind of stone found in the plains of Upper India, and used for metalling roads. It is a concretionary form of oolitic limestone.

Kurrie.—A small beam about 3 inches square.

Maund.—80 lbs. (28 go to a ton).

Monsoon.—The rainy season.

Musjid.—A mosque.

Nuddee.—A water-course, full in the rains but dry during the greater part of the year.

Pergunnah.—A sub-division of a Zillah or District.

Phourah.—A tool like a large hoe, which is the general substitute for the spade throughout India.

Pucka.—1. Cooked; burnt. 2. Full, complete, always opposed to *Kucha*.

Pucka masonry.—Is of burnt brick set in lime mortar.

Pucka Terrace Flooring or Roofing.—Is made of beaten lime over a foundation of brick.

Punkah.—A large fan hung from the ceiling and swung by manual labor to cool the air.

Rajbuha.—A minor water-course for Irrigation.

Rubbee (fusl).—The spring crop, wheat, &c.

Sál (Shorea robusta).—A valuable wood found in the Himalaya forests, and used generally in the N. W. Provinces for building purposes.

Seer.—2 lbs. (40 go to a maund).

Soorkhee.—Pounded brick, used for mixing with lime to make mortar.

Toon (Cedrela Toona).—A wood resembling mahogany, and used for similar purposes.